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THE UNIVERSITY OF NEBRASKA

TWENTY-FIFTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF

NEBRASKA

IMPERIAL BUREAU
28 JUN. 1921
OF MYCOLOGY

PRESENTED TO THE GOVERNOR FEBRUARY 1, 1912

LINCOLN, NEBRASKA
U. S. A.

LETTER OF TRANSMITTAL

THE UNIVERSITY OF NEBRASKA

AGRICULTURAL EXPERIMENT STATION

To His Excellency, Chester H. Aldrich, Governor of Nebraska:

SIR—In accordance with the act of Congress approved March 2, 1887, and the act of the general assembly of the State of Nebraska approved March 31, 1887, establishing and regulating experiment stations, I have the honor herewith to submit the Twenty-fifth Annual Report of the Nebraska Agricultural Experiment Station.

E. A. BURNETT,
Director.

February 1, 1912.

GOVERNOR'S CERTIFICATE

STATE OF NEBRASKA, EXECUTIVE DEPARTMENT,

LINCOLN, February 1, 1912.

Mr. E. A. Burnett, Director Nebraska Agricultural Experiment Station:

SIR—I hereby acknowledge receipt of the Twenty-fifth Annual Report of the Nebraska Agricultural Experiment Station.

CHESTER H. ALDRICH,
Governor.

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FRITZ KNORR, B. Sc., *Superintendent Experimental Substation,* Mitchell.
S. W. PERIN, *Farm Superintendent.*

* By an act of the legislature of the State of Nebraska approved and in effect February 15, 1899, the State Treasurer became *ex officio* custodian of the Experiment Station fund on and after July 1, 1899.
† Resigned.

TABLE OF CONTENTS

	PAGE
LETTER OF TRANSMITTAL	iii
GOVERNOR'S CERTIFICATE	iii
OFFICIAL ROSTER OF THE STATION	iv
DIRECTOR'S REVIEW—	
Experimental work	vii
Lines of Investigation	x
Plant diseases	x
Water requirements of corn	x
Determination of experimental error	xi
Selection of Turkey Red wheat	xii
Selection of seed corn	xii
Type of ears	xiii
Effect of crop rotation upon yield	xiii
Soil investigation	xiv
Seed potatoes	xv
Heredity investigations	xv
Forestry	xvi
Injurious insects	xvi
Relation of conformation to gaining capacity in cattle	xvi
Hog cholera serum	xvii
Cooperative experiments	xix
North Platte Substation	xx
Valentine Substation	xxii
Scotts Bluff Substation	xxii
Culbertson Substation	xxii
The Station Staff	xxiii
Improvements	xxiv
Publications	xxiv
Agricultural Extension	xxvi
Organized Agriculture	xxviii
FINANCIAL STATEMENTS—	
Hatch fund	xxix
Adams fund	xxx
Supplemental funds	xxxi
State projects—	
Farmers' Institutes	xxxii
Experimental Substations	xxxii

APPENDIX

PAGE

The Photometric and the Colorimetric Determination of Humus. By F. J. Alway and R. M. Pinckney 2
The Mineral Constituents of Some Soils of the Eastern Nebraska Loess. By F. J. Alway and E. K. Files 17
On the Sampling of Prairie Soils. By F. J. Alway and R. S. Trumbull, 35
On the Sampling of Cultivated Soils. By F. J. Alway and E. K. Files, 52
Some Notes on Alfalfa and Clover Residues as Sources of Soil Nitrogen. By F. J. Alway and E. S. Bishop 56
A Cooperative Investigation on the Losses of Nitrogen, Organic Matter, and Humus from Some Nebraska Soils. By F. J. Alway and E. S. Bishop 66
On the Determination of Soil Moisture. By R. S. Trumbull 71
The Determination of Total Manganese in Soils. By Ross A. Gortner and Clayton O. Rost 74
The Inheritance of the Ligule and Auricles of Corn Leaves. By R. A. Emerson 81
The Inheritance of Certain Forms of Chlorophyll Reduction in Corn Leaves. By R. A. Emerson 89
The Moisture Content of Field Soils Under Different Treatments. By P. B. Barker 106
Tests of Corn Planters with Graded Corn. By L. W. Chase and C. F. Chase 111
Soil Mulch. By H. J. Young 124
The Nitrogen Content of Some Nebraska Soils. By F. J. Alway and E. S. Bishop 129
The Relative Amounts of Nitrogen, Carbon, and Humus in Some Nebraska Soils. By F. J. Alway and C. E. Vail 145
Variation in Yield and Methods of Arranging Plats to Secure Comparative Results. By E. G. Montgomery 164
Preliminary Report on Effect of Close and Broad Breeding on Productiveness in Maize. By E. G. Montgomery 181
Evaporation from a Free Water Surface at Lincoln, Nebraska. By G. A. Loveland and S. W. Perin 193
Experiments with Tuberculin. By J. H. Gain 198
Some Investigations of the Cedar Rust Fungus, *Gymnosporangium juniperi-virginianae*. By George Herbert Coons 215
A Study of the Movement of Water in a Uniform Soil under Artificial Conditions. By F. J. Alway and V. L. Clark 246

TWENTY-FIFTH ANNUAL REPORT

EXPERIMENTAL WORK

The work of the Nebraska Agricultural Experiment Station for the current year has been as follows:

The funds for the Station are secured from three sources, namely: The Adams and the Hatch appropriations are received from the Federal Government in amounts shown by the financial statement of this report. The Experiment Station also uses certain other funds appropriated for general University maintenance and set aside by the Regents at their annual meeting for the maintenance of departments in the College of Agriculture and the Experiment Station. Direct appropriations are also made by the Legislature for certain specific purposes, such as hog cholera investigation and the work of State Entomologist and State Botanist, who are respectively Entomologist and Botanist of the Experiment Station. These appropriations are under control of the Regents of the University and are expended for the purposes authorized by the Legislature.

The State makes direct appropriations also for the maintenance of Substations at North Platte, Valentine, Mitchell, and Culbertson, Nebraska. An appropriation is also made for Farmers' Institute work, which in many ways is identical with extension work of the Experiment Station.

Under the law, the Adams fund must be expended strictly for original research and cannot be used for general administration, for printing, or for farm demonstrations. The Hatch appropriation may be used for general administration purposes and for investigation. It can no longer be used to print bulletins of a popular or demonstration character. State funds which come thru appropriation by the Regents to departments in the College

of Agriculture doing experimental work are available for all necessary purposes of investigation or demonstration, but these funds must largely be used in carrying on routine work which has been planned by the departments. The larger demands upon the departments caused by the growth of the Agricultural College leaves less and less money from State appropriations available for experimental purposes. A fund of not less than $25,000 annually should be appropriated specifically for this purpose at the central plant, as is now done for the branch Experiment Stations located away from the central plant.

Complete plans of work are prepared by each department at the beginning of the calendar year, covering the lines of investigation proposed for the current year. These are submitted to the Station Council for modification or approval. Plans are made for the utilization of all the funds available to the department, so that the work of the Station may progress in a systematic and orderly manner, so as to accomplish the largest results, and practically no funds remain unappropriated for the pursuance of new lines of work. Such lines of work can only be undertaken when the projects now under investigation have been completed. Most lines of work continue for a series of years before final completion. Problems requiring original research are always pressing for investigation, but funds for taking up new lines of work have been so limited that very few new projects have been undertaken in the last three or four years.

It is recognized by the men in the Experiment Station that one of the most important functions of the Station is to carry the results of experimental work to the people. This is done thru bulletins, thru farm demonstrations, and thru other methods of publicity. There is need at the present time of a rather large fund to use for demonstration purposes in cooperation with the farmers of the State. The present appropriation for Farmers' Institute work is not sufficient for that purpose, and was not intended to be used largely for demonstration purposes. Many

results of investigation are not adopted by the farmers because they do not have the information or they are not convinced that the methods recommended are adapted to their use. Farm demonstrations are intended to take the results of an experiment into a locality and show the people of the locality exactly how to use them. For example, our experiments have demonstrated that it is profitable for every dairyman to test each cow in his herd and determine the amount of milk and butter produced and the cost of maintenance. Some method should be devised by which cooperative cow testing associations can be organized among dairymen and the efficiency of this method demonstrated to the individual farmer. It is also well understood by those who have studied the development of the live stock industry elsewhere that cooperative breeding among farmers where whole communities shall use the same breeds of live stock tends to a higher efficiency of individual herds and a greater profit to the owners. It is necessary to go into some community and demonstrate these facts before they will generally be adopted by farmers. Methods of testing seed corn have been worked out so that they are fairly efficient. It is necessary at this time to interest individual farmers in breeding and selecting better corn for their own use. The Station could do this if it had funds to assist in the supervision of this work. It has been proved that summer tillage for winter wheat is profitable in average years in western Nebraska. The State and the county should cooperate in demonstrating this fact in a large number of communities so that the practice would be much more generally followed. There are many other lines of demonstration work which could be used to advantage to carry the general knowledge we already have at the Station to the farmer and induce him to put this knowledge into practice. It has been said that the methods of manufacturing butter are twenty-five years in advance of the methods of producing butter on the farm. It has been said that experimental knowledge for the improvement of farm practice is many

curate method of eliminating experimental error in growing crops, and a method of duplicating plats has been devised which tends to reduce the error to a minimum. This method is used in practically all of the experimental plat work at this Station.

Selection of Turkey Red Wheat.—The selection of pure strains of Turkey Red wheat was commenced at this Station in 1903 and is still in progress. Several thousand individual mother plants have been grown and from this number three have been selected which were grown last year under farm conditions in commercial quantities. Several other pure-bred strains are still under experiment.

Selection of Seed Corn.—For the past five years two methods of selecting seed corn have been used at this Station which promise good results. In the competitive method of growing seed corn, the seed plat is planted with more than a normal stand of corn, the experiments covering plats where one stalk per hill, two stalks per hill, three stalks per hill, four stalks per hill, and five stalks per hill were planted. The evidence shows that where the seed is selected from thick planting a smaller number of good seed ears are secured, but the average yield per acre from this seed when planted is higher than from seed which has been grown with one or two stalks per hill. This is probably due to the competition which comes from thick planting and which permits only the most vigorous plants to mature good ears.

Good results have also been secured in growing seed corn by the ear-to-row method, where selected ears of corn are planted in individual rows and the progeny from the high-yielding ears is used for field planting for the succeeding year. This ear-to-row method eliminates the seed from all ears which fall below a certain standard, and raises the average yielding power of the seed selected. To insure perfect cross-fertilization entire rows are sometimes detasseled and the seed is selected only from the

detasseled stalks. This insures perfect cross-fertilization of all the ears used for seed, which increases the yield.

Experiments carried on at this Station indicate that inbreeding of corn is detrimental to the yield and that corn which has been self-pollinated is not valuable for seed.

Type of Ears.—To determine whether there is any relation between the type of ear planted and the yield, 100 ears were planted in an ear-to-row test. Twenty-five ears each, of four distinct types, were selected. Considerable work has been done by way of studying the relation between type of ear planted and yield, and as yet no marked correlation has been found. The following table shows one year's results:

	Yield per acre Bushels
1. Very rough and rather large grained	36.24
2. Large ear—largest type among the ears, but not very rough, and grain of medium depth or less	33.87
3. Long slender ears, rather smooth and shallow in grain	36.13
4. Medium size ears, rather deep grain, deep indentation but not very rough	37.34

Effect of Crop Rotation upon Yield.—Work is in progress to determine the effect of crop rotation and continuous cropping upon the productiveness of Nebraska soils. Our data indicate that a frequent change of crops is necessary to the best production and that all farms in eastern Nebraska should be placed under rotations in which clover or alfalfa forms a part of the rotation. Quoting from the Twenty-fourth Annual Report:

"There are several reasons advanced for the wonderful effects upon the crop yields of corn grown upon alfalfa or clover land, among which is the increase of nitrogen content of soil, as shown by the dark green color of the succeeding corn crop when growing. This increase in nitrogen content has been noted by several Experiment Stations after careful chemical analyses of the soils before and after the growth of leguminous crops.

"The amount of organic matter added thru the addition to the

soil by the roots, stubble, and fallen leaves has no doubt a very great effect on the increased yield. The past fall the amount of alfalfa roots in the first eight inches was ascertained in an old field and found to be 2.3 tons per acre. When a three-inch stubble was considered in addition to the roots found in the first eight inches the amount of organic matter per acre in this way was increased to 3.2 tons per acre. These results were obtained from rather limited data and not as reliable as the results will be after more investigations along this line.

"Examinations of alfalfa fields made adjacent to the Station Farm, and also in Antelope county, indicate a large accumulation of nitrogen from the roots and the surface growth of clover and alfalfa. One alfalfa field which contained three tons of air-dried organic matter in the first foot of soil showed 125 pounds of nitrogen per acre stored in this organic matter. An alfalfa field one year old showed two tons of air-dry organic matter with 72 pounds of nitrogen. A clover field on the Station Farm in August, following the sowing of the clover in the spring without a nurse crop, showed 2,500 pounds of dry organic matter in the roots with 44 pounds of nitrogen present, and 4,500 pounds of dry organic matter in the tops with 137 pounds of nitrogen present, or a total of 8,000 pounds of organic matter and 181 pounds of nitrogen accumulated during the season of 1910, which had a heavy rainfall in August. This clover field produced a seed crop the same year the seed was sown. An old alfalfa field in Antelope county showed 5,100 pounds of dry organic matter in the first foot of soil with 105 pounds of nitrogen, and 4,100 pounds of dry organic matter in the next 10 feet of soil containing 65 pounds of nitrogen, or a total of 9,200 pounds of organic matter in the alfalfa roots contained in the first 11 feet of soil, carrying a total of 170 pounds of nitrogen."

Soil Investigation.—An exhaustive study of the soils of the loess area is in progress, to determine the relation between the chemical composition and physical properties of these soils and the rainfall where they occur. The samples were secured from six areas, viz., Weeping Water, Lincoln, Juniata, Holdrege, McCook, and Wauneta, the first having a normal annual rainfall of a little over 30 inches and the latter of 21 inches.

The investigation of the alkali soils of the Fremont drainage area has been continued, and a report is in process of preparation.

Seed Potatoes.—In the tests of potato seed tuber production, the following practical points have been determined:

1. The use of home-grown seed in eastern Nebraska from the same stock of tubers year after year results in a decided decrease in total yield and increase in per cent of small unmarketable tubers as compared with the use of northern-grown seed.

2. Seed grown under a litter mulch in eastern Nebraska is equal to the best northern-grown seed.

3. Deterioration of the stock from the use of home-grown seed is gradual and cumulatve, seed grown several years at the Station always being poorer than that grown only one or two years.

4. One year of mulching brings the productiveness of rundown stock of potatoes back to normal conditions. In our test one year's use of the mulch has produced practically as good results as seven years' continuous mulching.

5. Hay, straw, and stable litter are about equally good as a mulch for the production of seed tubers as regards the effect of the next season's crop. On rather poor soil, stable litter usually gives the best immediate yield of seed tubers.

6. To get the full value of the mulch in producing good seed, it must be applied by the time the tubers begin to form.

7. The expense of producing high-grade seed tubers by mulching under farm conditions need not be greater than that of producing the same quality of poorer seed by means of cultivation.

Heredity Investigations.—Heredity investigations have been continued during the current year and the vast amount of data bearing upon Mendel's law as affecting size, color, hardiness, and other characters in plants has been compiled and will soon be ready for publication.

Forestry.—Experiments are in progress to determine the most suitable thickness of planting and the most desirable methods of thinning leading hardy trees at the central Station. A study is being made of the desirability of cutting catalpas back to the ground after one or two years' growth, for the purpose of growing fence posts. This practice has been generally recommended by foresters.

The hardiness of varieties and the distance of planting is under observation at the North Platte Station.

Methods of treating fence posts with creosote will be studied to determine the efficiency of such treatment upon cottonwood, box-elder, elm, and other varieties of wood not durable under natural conditions.

Injurious Insects.—Experiments are in progress to determine the life history, parasites, and feasible means of control of the pine-tip moth, which has greatly injured the young pines on the forest reserve at Halsey. The investigation is continued.

A study of grasshopper control-measures was in progress during the season of 1911 and will be continued during 1912.

A study of the insect enemies of alfalfa is in progress.

Relation of Conformation to Gaining Capacity in Cattle.—Forty-eight steers, all born in June, 1910, have been used in a feeding experiment to determine the relative value of different rations in beef production. These steers have also been used to determine the relation of conformation to economy of growth.

The rations were made up to determine the value of silage for summer feeding. Group 1 was fed corn, alfalfa, and corn-stover; Group 2, corn, alfalfa, and corn silage. Enough additional grain was fed with the stover to make up for the corn present in the silage. The silage-fed steers gained 15 pounds per month more than the stover-fed steers. Group 3 was fed corn, cottonseed-meal, and corn silage; Group 4, corn, linseed-meal, and corn silage; Group 5, corn, bran, and corn silage. In all

these groups the grain ration fed was about three-fourths of a full ration. The gains were highest in the alfalfa-fed group that received silage. The second best gain was with corn, linseed-meal, and corn silage; the third best with corn, cottonseed-meal, and corn silage. The gains in the bran-fed group were not only the lowest but much more expensive. Group 6 was fed a full ration of corn, cottonseed-cake, and corn silage. The gains made by these steers were larger than in any group fed on a smaller grain ration, but these gains were made at a higher cost and were less profitable. It was shown in this test that where alfalfa was fed with silage the gains were made on 25 per cent less corn than where corn, cottonseed-cake, and silage was fed without alfalfa.

In each of the six groups were steers of different types, some good and some inferior, upon which individual records were kept to secure data on the correlation of type with gains. Each individual has been measured at intervals to determine the relation between type and gaining capacity, and to determine the tendencies toward change in type with increased fatness and maturity.

Hog Cholera Serum.—An appropriation of $15,000 was made by the last Legislature to establish a plant for the production of hog cholera serum. The plans for the building which is to house this work were delayed in the hands of the architect, but the building is now under construction and will be completed by March or April. In the meantime serum has been produced in a temporary plant and 400,000 cubic centimeters have been furnished to farmers in the State, with quite satisfactory results. Under the law, this serum is sold at the approximate cost of production and the price of two cents per cubic centimeter has been charged for the serum sent out. From this time on we shall be able to produce a much larger amount of serum and hope to be able to supply the demand at the time when cholera outbreaks are not too numerous. The present plant, however, will

not be able to supply any large part of the serum demanded in times of serious outbreak. The theory of the use of serum to prevent cholera is that it shall be used upon all herds whenever outbreaks occur and in this way entirely stamp out the disease where farmers use the necessary precautions and vaccinate upon the first appearance of the disease. It will probably be many years before all farmers will be educated to the proper use of serum and a sufficient amount be produced to permit its prompt use as soon as an outbreak occurs. Some unfavorable results have occurred where serum has been used. These are due to one of three causes:

First—The presence of cholera in a slow or mild form which does not show upon the animal until after the disease has been present for some days. Under this condition, supposed healthy hogs are frequently vaccinated with serum when in fact they already have cholera in a mild form, as shown when the temperature of the hog is taken. Hogs with abnormal temperatures in cholera herds cannot be protected by serum, even tho they do not show the ordinary physical symptoms.

Second—Hogs which are shipped to eastern Nebraska from other sections where cholera has not been known are more susceptible to outbreaks of cholera than those which have been grown in the cholera districts and which have been produced from parents having greater resistance to the disease, or, in other words, from parents which possess some degree of immunity. The hogs which are shipped from sections where no cholera exists require a larger amount of serum for protection than those grown in cholera-infected regions.

Third—In the "simultaneous method" of treatment, the condition of the virus used with the serum may not always be normal, and this abnormal virus may produce unfavorable results, even when the serum is of proper quality. To insure protection by the simultaneous method, serum should be administered to the

hogs without the application of cholera virus. After a period of ten days, serum and virus should be administered simultaneously. Under this method of treatment, mild cases of cholera are produced from which the animal soon recovers, and the immunity is permanent. Some loss is liable to occur under the simultaneous method of treatment, but this loss should not be great, especially under the precautions mentioned above.

A detailed description of the methods of treating hogs with serum is given in Experiment Station bulletins.

COOPERATIVE EXPERIMENTS

The Station is cooperating with a number of farmers in testing the selected strains of Turkey Red wheat developed at this Station. Twenty-one farmers raised these improved strains of wheat in 1910-1911, and twenty-one additional farmers are cooperating in 1911-1912. The average yield per acre secured by the twenty-one farmers last year was a little more than four bushels in excess of the yield from their own seed sown upon the same field. Eight acres of the improved strain in each case was sown as a part of a larger field. The increase in yield was shown mainly upon those fields which produced normal or more than normal yields from local seed. In some instances where all yields were poor, the yield from the selected seed did not equal the yield from the local seed.

The Station is cooperating with a number of farmers in Polk county, known as the Polk County Corn Club, to work out a practical system for the selection of improved seed corn which can be used by any intelligent farmer. At the present time fourteen men in one neighborhood are cooperating. The two methods in use are:

First.—To plant the seed plat with more than a normal stand, about five stalks per hill, detasseling every other row in the seed plat, thus preventing self-fertilization, and select seed only from plants which have developed normal and vigorous ears under this competitive method.

Second.—Seed is grown under the ear-to-row method, in which selected ears of seed are grown in single rows and the yield per acre determined. Only the selected seed from high-yielding ears is used for field planting during the year following.

Either of these methods is simple enough to be used by the farmer who is willing to give a little additional labor to the raising of superior seed corn for his own use.

This Station is in cooperation with the Bureau of Plant Industry in conducting a plant disease survey of the State, reports of which are made from time to time. A handbook of Nebraska plant diseases is in process of preparation.

The North Platte Experiment Station is cooperating with the Bureau of Plant Industry in its Dry Land Agriculture investigations, to determine the methods of tillage and the crop rotations most suitable to the Great Plains area. The Station is also cooperating with the Bureau of Plant Industry in studying the same problems at the Substation at Mitchell, Nebr., this Station being under the direct supervision of the United States Department of Agriculture.

THE NORTH PLATTE SUBSTATION

The North Platte Substation has been in operation since 1904. Its lines of investigation have been described in previous Reports, and nine bulletins upon tillage, crop rotation, varieties, cattle feeding, swine feeding, etc., have been published.

The year 1911 was the most disastrous in the history of the Station. Practically all small grain crops were destroyed by summer drouth and hot winds. The winter wheat raised upon summer tilled land on the table was destroyed by winterkilling and spring drouth. The winter wheat on the bench land or second bottom made an average of about 13 bushels per acre, whereas the five-year average before 1911 was 46 bushels per acre and the six-year average, including 1911, was 40 bushels per acre. It requires two years to produce a crop by this system,

so that the land is in use for two years to produce the average crop above mentioned. Bulletins 114 and 118 specially deal with summer tillage and with crop production at this Station, and are available for distribution.

Since the establishment of the Station, pig feeding experiments have been carried on, using nearly 1,000 pigs to determine the most economical methods for growing pork in the Great Plains area. Bulletin 121, recently published, and 123, in press, give summaries of this work.

The Station has also carried on lines of investigation covering the growing of steers for the feed-lot, and has reported its investigations in Bulletin 117, which is available. We are also conducting at this Station an investigation in the production of baby beef, placing calves at weaning time in the feed-lot and feeding them for market under approved methods with the expectation of marketing them at an age of from fourteen to sixteen months. The present experimental work covers the use of the following rations, namely:

1. Corn, cottonseed-meal, and prairie hay.
2. Corn, alfalfa 80 per cent, prairie hay 20 per cent.
3. Corn, silage, and alfalfa.
4. Corn, silage, and prairie hay.
5. Corn, cottonseed-meal, silage, and prairie hay.

The season just past in western Nebraska should not discourage the farmer who is located in the region named, but it should teach him the necessity of organizing his farm operations so that severe drouth years shall not be fatal to his success. He should, if possible, carry over forage in normal years to be used in years of drouth. He should keep some land in pasture and should keep live stock in connection with the farm. Dry farming in western Nebraska cannot prosper as a grain farming system. The risk is too large in a dry season. Live stock must be the basis of production thruout all the dry region in Nebraska.

THE VALENTINE SUBSTATION

The Substation at Valentine has been established since 1910. Most of this period has been used in establishing a plant and laying out experiments suitable to the sand hill region. The season of 1911 was unfavorable to Valentine as well as to other sections in western Nebraska. While some crops were raised, most crops were destroyed by hot winds and drouth.

Plans are being perfected to establish a dairy herd on the Station farm at Valentine and to work out the problem of growing leguminous crops upon this sandy land along with other crops which can be used for forage.

THE SCOTTS BLUFF SUBSTATION

The Scotts Bluff Substation is operated by the Bureau of Plant Industry of the United States Department of Agriculture. Experiments are being conducted both with dry land farming and with irrigation methods to assist the homesteaders who have located upon lands under the Reclamation Service. The State cooperates in this work by making a small appropriation. The principal lines of investigation cover methods of tillage and rotations most suitable for the region under both dry land and irrigation systems. Special experiments are being conducted with sugar beets, potatoes, etc. This work has been in progress since 1909.

THE CULBERTSON SUBSTATION

The last Legislature made an appropriation to establish a Station at Culbertson, Nebr., under such conditions as the Regents of the University might determine. After several trips of investigation, the Regents, on April 13, 1912, purchased from Mr. W. H. Ferguson the southeast quarter of section 9, township 3, range 31 west, 160 acres of land, for a Demonstration Farm at Culbertson. Only a portion of this land comes into possession of the University at this time, the balance being available when the winter wheat crop is harvested. This land

lies one-half mile east of the town of Culbertson, on the north side of the main traveled road. It slopes toward the road, is somewhat rolling, and is all under ditch, so that it may be irrigated. This is a private ditch, so that no water right was acquired with the land.

THE STATION STAFF

Within the past year the following changes in the Station staff have taken place:

Professor A. L. Haecker, for 15 years in charge of the Dairy Department, resigned to take up commercial work. September 1, 1896, he was made Instructor in Dairying and Assistant in Agriculture, and on July 1, 1901, was given full charge of the Department of Dairy Husbandry. He is succeeded by Professor James H. Frandsen, who on October 1, 1911, took charge of this Department, coming to the State from the University of Idaho, at Moscow.

Professor E. G. Montgomery, for four years in charge of Experimental Agronomy, resigned January 1, 1912, to accept a position in the College of Agriculture of Cornell University. His successor has not been appointed.

Professor H. R. Smith, for eleven years Professor of Animal Husbandry, resigned February 1, 1912, to accept a similar position in the College of Agriculture of the University of Minnesota. His successor has not been appointed.

Professor Frank J. Phillips, in charge of the Forestry work, died February 13, 1911.

Professor C. W. Pugsley, in charge of Soil Agronomy, was transferred to the Department of Agricultural Extension as Superintendent of Agricultural Extension and Farm Management. He remains in charge of Farm Management investigations.

Miss Venus W. Pool resigned November 1, 1911, to accept a position in the Bureau of Plant Industry, United States Department of Agriculture.

IMPROVEMENTS

Since the last Annual Report, a laboratory has been erected for the production of hog cholera serum, at a cost of $5,000. This building is constructed of hollow tile covered with cement stucco.

The Horticultural laboratory has been moved from its original site to make place for a natural science building which is to house the departments of Agricultural Botany, Horticulture, and Entomology. This building is to be fireproof and is to cost $85,000. The contract has been let, but construction on the building has not yet commenced.

At the North Platte Station a dwelling-house, to be used for housing and boarding farm help, is under construction. This house is built of hollow tile covered with cement stucco. It will cost $8,000. A sewer system is also in process of construction.

At the Valentine Substation a dairy barn is under construction as an annex to the present horse barn. This building will be constructed of cement block, in harmony with other buildings at the Valentine Substation, and will cost $3,000.

PUBLICATIONS

Regular bulletins giving the results of investigation in the Experiment Station are published in editions of from 20,000 to 40,000 each. Technical bulletins are published in limited editions and are sent out only to scientific men working in the same field and to others upon application. There is at the present time a regular mailing list within the State of 17,000 names. These are continually being added to, and it is desired that all farmers who are interested in the publications of the Station should ask to be placed on the mailing list. The Station is attempting to classify its mailing list under the general subjects of soil fertility and crop production, animal diseases, feeding animals, plant diseases and insect pests, and orchard management. A general mailing list will be continued for those who desire all bulletins,

but the expense of publication has become so large that we feel the necessity of sending bulletins only to those who are sufficintly interested in the subject to give the bulletin careful consideration.

The publications of the Station since those named in the last Annual Report are as follows:

Twenty-fourth Annual Report. Presented to the Governor February 1, 1911. 5,000 copies.

Bulletin No. 119 (Volume XXIII, Article IV). Spraying as an Essential Part of Profitable Apple Orcharding. By R. A. Emerson, R. F. Howard, and V. V. Westgate. Distributed March 15, 1911. 25,000 copies.

Bulletin No. 120 (Volume XXIII, Article V) (Extension Bulletin No. 1). Alfalfa Management. By C. W. Pugsley. Distributed May 12, 1911. 40,000 copies.

Bulletin No. 121 (Volume XXIII, Article VI) (Substation Bulletin No. 8). Growing Hogs in Nebraska. By W. P. Snyder. Distributed June 30, 1911. 32,000 copies.

Bulletin No. 122 (Volume XXIII, Article VII) (Extension Bulletin No. 2). Cost of Growing Crops in Nebraska. By C. W. Pugsley. Distributed June 30, 1911. 32,000 copies.

Bulletin No. 123 (Volume XXIV, Article I) (Substation Bulletin No. 9). Fattening Hogs in Nebraska. By W. P. Snyder. (In press.) 30,000 copies.

Bulletin No. 124 (Volume XXIV, Article II) (Substation Bulletin No. 10). Fattening Hogs in Nebraska. By W. P. Snyder. (In press.) 5,000 copies. (Technical bulletin.)

Bulletin No. 125 (Volume XXIV, Article III). Wheat Breeding Experiments. By E. G. Montgomery. (In press.) 30,000 copies.

Bulletin No. 126 (Volume XXIV, Article IV). Native Seed Corn. By E. G. Montgomery. (In press.) 30,000 copies.

Press Bulletin No. 34. How to Combat the Melon Aphis. By M. H. Swenk. Distributed June 26, 1911. 21,000 copies.

Press Bulletin No. 35. Catch Crops for Hay and Pasture. By E. G. Montgomery. Distributed July, 1911. 2,500 copies.

Press Bulletin No. 36. The Distribution and Use of Hog Cholera Serum. By J. H. Gain. Distributed September 26, 1911. 35,000 copies.

AGRICULTURAL EXTENSION

The department of Agricultural Extension has taken over the work formerly done by the department of Farmers' Institutes. Several members of the Experiment Station staff have assisted in institutes during the current year. About 125 institutes were held during the year 1910-1911 previous to April 1. Between October 1 and December 31, 1911, 90 institutes were held, and between January 1, 1912, and October 1, 1912, it is expected about 200 points will be reached, 400 days being devoted to institutes at these institute points.

In addition to regular institutes, nine junior short courses and probably five senior short courses or institute schools covering a period of one week each will be held at different points in the State.

A number of seed-corn trains will be operated by the railroads, covering nearly all the territory on the leading railroad lines of the State. The speakers upon these trains will be in charge of the Agricultural Extension Department of the University. The expense of operating these trains, other than the speakers, will be borne by the railroads or the grain exchanges of the State.

The Extension Department of the University is offering two correspondence courses in agriculture for farmers, teachers, county superintendents, and others.

The appropriation for extension work is $17,500 per year.

Many lines of extension work not yet undertaken should be developed in Nebraska. These should be in the direction of farm demonstrations which will assist the farmers in adopting new methods which have been developed by the Experiment Station but which have not yet come into general use.

An agricultural survey should be made to determine the relative cost of producing beef and pork upon farms where alfalfa is used as a part of the ration in comparison with other rations; also where silage is used as a part of the ration in comparison with rations where no silage is used. When these data are gathered, they should be given publicity so that other farmers may know the results which are actually being obtained upon farms at the present time.

Similar lines of work should be carried on to determine the production of individual cows in dairy herds and the net profit per cow. This will encourage the keeping of individual records by farmers and will increase the average production and profit from dairying.

An agricultural survey should be made covering the different systems of farming in some typical region of the State, showing the value of the land, the labor expended on the same, the capital invested in live stock and machinery, and the profits if any upon the investment, with the view of classifying these different farms into groups, to determine what method of farming gives the largest return for the capital and labor invested in the business.

Demonstrations should be conducted in southeastern Nebraska covering the management of commercial orchards, to determine what method will give the largest practical results. The results of the application of scientific methods to orcharding will very greatly stimulate the growth of orchards in eastern Nebraska especially along the Missouri river bluffs, which furnish natural opportunities for orcharding probably equal to any region in the United States.

The effect of summer tilling on the production of winter wheat should be demonstrated upon many farms in western Nebraska to determine the practicability of using summer tillage methods on the average farm.

The men who are engaged in these lines of agricultural survey will soon become competent and practical advisers of the farmers who need assistance in these various lines.

The Extension School, or the Farmers' Short Course, should be extended to many farming regions of the State. A school of one week or two weeks should be held for the discussion of agricultural subjects with practical farmers and the sons of these farmers who cannot attend other agricultural schools will be of enormous value in carrying practical agricultural methods to the people.

Agricultural short courses are conducted for both men and women, separate sections being organized for women, who discuss subjects relating to the improvement of the home.

The appropriation for extension work along the lines mentioned should be very greatly increased, as the appropriation now available is only sufficient for carrying on the Farmers' Institutes and the few Extension Schools mentioned in the above report.

ORGANIZED AGRICULTURE

The meetings of Organized Agriculture have been well attended and are a source of great interest and profit to those in attendance. Several of these associations are now incorporated and receive small appropriations from the State to assist in publishing their annual reports. These meetings bring together many of the leading farmers of the State for discussions which are of large economic value, and should be attended by all progressive farmers.

THE AGRICULTURAL EXPERIMENT STATION OF NEBRASKA

FINANCIAL STATEMENT

HATCH FUND

RECEIPTS.

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1911, under the act of Congress approved March 2, 1887 (Hatch fund)	$15,000 00

EXPENDITURES.

Salaries		$8,899 87
Labor		1,471 97
Publications		2,131 11
Postage and stationery		496 61
Freight and express		64 99
Chemicals and laboratory supplies		14 88
Seeds, plants, and sundry supplies		219 66
Feeding stuffs		609 01
Tools, machinery, and appliances		120 15
Furniture and fixtures		131 40
Scientific apparatus and specimens		2 06
Live stock		547 98
Traveling expenses		123 52
Contingent expenses		25 00
Buildings and land		141 79
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

ADAMS FUND

RECEIPTS.

Received by the University (state) treasurer from the treasurer of the United States, installment for the fiscal year ended June 30, 1911, under the act of Congress approved March 16, 1906 (Adams fund)	$15,000 00

EXPENDITURES.

Salaries		$8,502 50
Labor		2,576 62
Postage and stationery		46 37
Freight and express		88 52
Chemicals and laboratory supplies		160 70
Seeds, plants, and sundry supplies		591 09
Feeding stuffs		761 87
Tools, machinery, and appliances		180 96
Furniture and fixtures		318 75
Scientific apparatus and specimens		758 61
Live stock		312 63
Traveling expenses		701 38
	$15,000 00	15,000 00

FINANCIAL STATEMENT—Continued

SUPPLEMENTAL FUNDS

RECEIPTS.

Moneys received by the University (state) treasurer from other sources than the United States, for the use and benefit of the experiment station and substations for the year ended July 31, 1911:		
Balance, July 31, 1910	$8,688 20	
Sales of stock, produce, etc., for year ended July 31, 1911	35,808 33	

EXPENDITURES.

Salaries		$6,982 72
Labor		4,894 40
Publications		32 98
Postage and stationery		613 98
Freight and express		493 98
Chemicals and laboratory supplies		29 02
Seeds, plants, and sundry supplies		5,131 11
Feeding stuffs		12,184 02
Tools, machinery, and appliances		1,317 51
Furniture and fixtures		250 00
Scientific apparatus and specimens		305 16
Live stock		4,836 09
Traveling expenses		785 42
Buildings and land		2,501 00
Balance, July 31, 1911		4,139 14
	$44,496 53	44,496 53

FINANCIAL STATEMENT—Concluded

STATE PROJECTS

Farmers' Institutes—			
Balance, July 30, 1910		$7,131 04	
State General Fund appropriations, two years ending March 31, 1913		35,000 00	
Expenditures, one year to July 31, 1911			$7,698 39
Appropriation balances, July 31, 1911			34,432 65
		$42,131 04	42,131 04
Experimental Substations—			
Balances, July 30, 1910:			
North Platte		$5 07	
Scottsbluff		3,614 02	
Valentine		10,943 93	$14,563 02
State General Fund appropriations two years to March 31, 1913—			
Culbertson		15,000 00	
North Platte		30,000 00	
Scottsbluff		5,000 00	
Valentine		15,000 00	65,000 00
			$79,563 02
Expenditures, one year ended July 31, 1911—			
North Platte	$5,710 84		
Scottsbluff	3,898 26		
Valentine	13,640 21	$23,249 31	
Balances July 31, 1911—			
Culbertson	15,000 00		
North Platte	24,294 23		
Scottsbluff	4,715 76		
Valentine	12,303 72	56,313 71	
		$79,563 02	79,563 02

J. S. DALES,
Financial Secretary.

January 31, 1912.

APPENDIX

THE PHOTOMETRIC AND THE COLORIMETRIC DETERMINATION OF HUMUS

By F. J. Alway and R. M. Pinckney

The determination of that portion of the organic matter of the soil which is soluble in dilute alkalies and which is known as humus (*matière noire* of Grandeau) is beset with various difficulties, which are well illustrated by the history of the method in use by the Association of Official Agricultural Chemists of the United States. The modification of the Grandeau method suggested by Hilgard, and in the following pages referred to as the *Hilgard method,* when properly carried out is capable of giving concordant and reliable results. With many soils, however, it is extremely tedious, the complete removal of the humus in some cases being accomplished only after from ten to twenty days of continuous extraction.[1] Partly in order to overcome this difficulty the Huston-McBride[2] method was adopted by the Association of Official Agricultural Chemists of the United States, about eighteen years ago, and has been retained up to the present time. While by this—now generally known as the "official"—method the time required for the determination of humus, where only a few soil samples are being analyzed, is greatly shortened, the results are entirely unreliable, the error amounting to from 15 per cent to over 200 per cent of the humus present.

The chief source of error in the accurate determination of humus lies in the difficulty of obtaining an ammonia extract which contains all of the humus while at the same time it is practically free from clay. Even if the extraction has been exhaustive and the extracts free from clay, the gravimetric determination, where a large number of samples are to be an-

alyzed, is a slow process. Platinum evaporating dishes are required and, with the high price of platinum prevailing, the cost of each dish is between $60 and $100, and each dish will permit of the determination of but a single sample in duplicate in the course of twenty-four hours, the evaporation being continued night and day.

A few years ago, having occasion to make determinations of the humus in a large number of soil samples from different parts of Nebraska, and in a considerable number of samples from Saskatchewan, and wishing to know the approximate humus content of the different samples long before it could be learned from the gravimetric determinations, the humus extracts were prepared in lots of from 50 to 120 at a time and at once subjected to the photometric or the colorimetric determination described below. Then, as rapidly as was possible, gravimetric determinations were made in the case of all the extracts. Accordingly, we have a large amount of data from which to judge of the reliability of the methods. Part of these data are given in the following tables. At the time the determinations were made we did not appreciate the difficulty of removing the last traces of humus by the Hilgard method and accordingly many of the analyses were later rejected and new and more exhaustive extractions made, but on these no photometric determinations were made. This, however, probably does not affect the value of the earlier determinations for the study of the subject dealt with in this article.

The results lead us to the conclusion that for Nebraska soils very low in humus (under 0.30 per cent) the colorimetric method is as accurate as, or even more accurate than, the gravimetric method, while for Nebraska soils containing 1 per cent or more of humus the photometric method gives results approximately correct, provided that certain precautions are observed. The latter method is applicable only where the humus content is moderately high and the former was tried only where the

humus content was low. The two methods are so similar in their essentials that they are to be regarded as different modifications of the same method, rather than as two distinct methods.

All the data on the following pages are from Nebraska and Saskatchewan soils, and we should here mention that in the case of a number of desert soils which we examined satisfactory results were not obtained.

The Standard Solutions.—For both the photometric method and the colorimetric method the choice of a standard solution and the determination of the humus in it are of first importance. In the determinations reported below, the standard selected was the humus extract from a soil of the same type and from the same locality as the series of samples being analyzed. In some series a second standard from a different locality was used and is reported in order to show the extent to which the same standard may be used for soils from different localities. The determination of the humus in the standard solution was made gravimetrically.

The Photometric Method.—As a source of light a candle is used, it being placed in a box with a hole half an inch in diameter in the top. The candle is held in a clamp 24 inches below the top of the box. Two Hehner cylinders, both of the same internal diameter, are connected by means of a rubber tube, both stop-cocks closed and the one cylinder partly filled with the standard solution. The empty cylinder is placed over the opening in the top of the box and the cylinder containing the standard solution supported on a stand at a height of 6 to 12 inches above the former. After lighting the candle and darkening the room as much as possible, the stop-cock of the higher cylinder is opened wide. While the operator has one hand on the stop-cock of the lower cylinder and has one eye above the latter, watching the candle flame, the solution is allowed to slowly enter until the flame just disappears. Then the stop-cock is closed and the height of the column of solution recorded, after

which the lower cylinder is raised and the stop-cock opened so that part of the solution flows back into the other cylinder. Then the determination is repeated until two or three successive readings give approximately the same height, the average of these being used in the calculation.

After thus determining the depth of the column of the standard extract required to hide the candle flame, similar determinations were made with all the extracts. It much simplifies the calculations if in all cases equal weights of soil have been extracted and the extracts have been made up to the same volume. We used 10 grams of soil in each case and made the volume of extract up to 250, 500, or 1,000 c.c., according to the amount of ammonia solution required to fully extract the humus.

Where the same graduated cylinders, both of the same internal diameter, are used in all cases, it suffices to record the volume of the extract required to hide the candle flame. Otherwise, it is necessary to measure the depth of the column of solution. In case one of the pair of cylinders should be broken and another of different internal diameter should have to be substituted, it becomes necessary to employ a measuring stick and to record the height of the column of solution. In all cases it is desirable at the beginning of each series of determinations to enter in the record book the height of the 50 c.c. or 100 c.c. mark above the bottom of the cylinder. This will permit in the end the use of many different standards—as many as there are soils of which the humus has been determined gravimetrically, as well as photometrically.

Provided that the same weight of soil has been used and that the humus extracts have been made up to the same volume, the percentages of humus will be inversely proportional to the heights of the columns of extract required to hide the candle flame. Where the cylinders are of the same internal diameter and where, hence, the relative heights of the columns are the same as the relative volumes of solutions required, the volumes

may be recorded and used in the calculations. The following extract from a page of a record book will illustrate the completeness and the character of the notes that we have found desirable:

Standard—Soil A. 10 grams extracted and extract made up to 500 c.c. For all soils in this series, weight of soil and volume of extract the same. Cylinders of the same internal diameter with 100 c.c mark at height of 152 mm.

Soil	Volume required	Humus
	c.c.	*Per cent*
A. Standard	52	2.20
A.	53	2.15
A.	54	2.22
A.	54	2.13
Average	53	2.18
B.	32	...
B.	31	....
Average	31.5	3.67
C.	57	....
C.	59	....
Average	58	1.99

The Colorimetric Method.—This is preferable in the case of dilute solutions of humus—those in which the humus solution to a depth of 150 mm. will not hide the candle flame. In this case a standard is prepared as above and then of this a measured volume is diluted to 100 c.c. or to 500 c.c., and an aliquot portion, say 50 c.c., is placed in a Hehner or a Nessler cylinder. This is held beside a similar, but empty, cylinder vertically over a white plate in a good light. To the empty cylinder the humus solution under examination is slowly added until the same tint is observed in both. The results are most accurate when the standard is diluted to such an extent that the diluted solution is of about the same color as the solution under examination. The following extract from one of our record books will serve for further explanation:

Standard—Soil A. 10 grams extracted to make 500 c.c. extract. Humus, det'd gravimetrically=2.18 per cent. Diluted 50 c.c. of above extract to 500 c.c. and used 50 c.c. of the diluted standard. For all soils in this series, weight of soil was 10 grams and vol. of extract 250 c.c. Used cylinders of the same internal diameter. 100 c.c. mark at 152 mm.

Soil No.	Volume required	Humus
	c.c.	*Per cent*
Standard (A)	50	0.22
F	40	....
F	42	....
Average	41	0.27
G	63	....
G	65	....
Average	64	0.17

As, after one has become familiar with the method, over one hundred humus determinations can be made satisfactorily in the course of an eight-hour day, the gain in rapidity over the gravimetric method is evident. Of course the solutions require the same time for preparation and the humus in the standard must be determined gravimetrically.

Table 1 shows the percentages found by the photometric method compared with those found by the gravimetric in the case of 57 samples of soil from the Experimental Farm at Indian Head, Saskatchewan. All the samples were from the surface six inches. The history of the plots and fields, the method of sampling, etc., have already been given elsewhere.[3]

The photometric determinations were made on December 17, 1907, and were repeated on the following day. From these two sets of determinations it may be seen how concordant the photometric determinations are when the results are uninfluenced by a previous knowledge of the approximate depth of solution required to hide the candle flame. The average of the two photometric determinations is used in comparison with the gravi-

metric determination. In the table the samples are reported in the order of the percentage of humus as found by the gravimetric method. Thus, there is shown the concordance of the gravimetric determinations with the photometric, and the concordance of duplicate determinations by the latter method with one another, as well as the relative ranking of the samples when the humus has been determined by the two methods. In general the relative ranking is similar but not identical, those samples found to be rich, intermediate, or poor in humus by the one method being found to be rich, intermediate, or poor by the other method, altho the samples poor in humus may not have the same ranking. Three samples, 718, 719, and 731, gave decidedly lower results by the photometric method than by the gravimetric. The studies for which the gravimetric determinations were made have already been published.[3] If in these the results of the photometric determinations had been used instead of those of the gravimetric, the conclusions drawn would have been essentially the same. In this series of samples we have a great range in the humus content, viz., from 1.57 to 6.11 per cent.

TABLE 1.—*Humus in soils from the Indian Head Experimental Farm. For the standard, one of the series (No. 702) was used.*

Soil No.	Gravimetric	Photometric				Difference between gravimetric and photometric
		Dec. 17	Dec. 18	Average	Difference	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
703	6.11	6.67	6.81	6.74	.14	.63
725	5.98	5.14	4.99	5.07	—.15	—.91
727	4.82	4.39	4.15	4.27	—.14	—.55
728	4.22	3.83	3.64	3.73	—.19	—.49
717	3.25	2.68	2.52	2.60	—.16	—.65
715	3.02	2.77	2.49	2.63	—.28	—.39
732	2.92	2.40	2 26	2.33	—.14	—.59
735	2.88	3.00	2.90	2.95	—.10	.07
718	2.77	2.07	1.83	1.95	—.24	—.82
714	2.73	3.00	2.76	2.88	—.24	.15
716	2.71	2.77	2.68	2.72	—.09	.01
731	2.58	2.19	2.02	2.10	—.17	—.48

TABLE 1.—*Humus in soils from the Indian Head Experimental Farm—Concluded.*

Soil No.	Gravimetric	Photometric				Difference between gravimetric and photometric
		Dec. 17	Dec. 18	Average	Difference	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
719	2.53	1.83	1.80	1.81	—.03	—.72
681	2.49	2.25	2.07	2.16	—.18	—.33
736	2.48	2.72	2.52	2.62	—.20	.14
743	2.46	2.19	2.27	2.23	.08	—.23
742	2.32	2.17	2.12	2.15	—.05	—.17
704	2.30	2.25	2.27	2.26	.02	—.04
706	2.29	2.17	2.12	2.14	—.05	—.15
707	2.28	2.07	2.02	2.04	—.05	—.24
708	2.28	2 17	1.98	2.07	—.19	—.21
705	2.26	2.25	2.25	2.25	.00	—.01
741	2.24	2.07	2.05	2.06	—.02	—.18
729	2.23	1.85	1.82	1.84	—.03	—.39
696	2.21	2.07	2.02	2.05	—.05	—.16
739	2.16	1.87	1.81	1.84	—.06	—.32
682	2.13	2.00	1.87	1.93	—.13	—.20
738	2.12	2.02	1.87	1.94	—.15	—.18
737	2.10	2 02	1.78	1.90	—.24	—.20
697	2.10	2 04	1.93	1.98	—.11	—.12
687	2.07	2.04	2.00	2.02	—.04	—.05
698	2.05	2.00	1.93	1.97	—.07	—.08
681	2.05	1.87	1.89	1.88	—.02	—.17
733	2.05	2.22	2.05	2.14	—.17	.09
690	2.05	2 09	2.10	2.09	.01	.04
709	2.03	1.93	1.74	1.83	—.19	—.20
699	2.03	2.14	2.02	2.08	—.12	—.05
702	2.00	2.00	2.00	2.00	...	...
692	2.00	2.04	2.02	2.03	—.02	.03
693	1.94	1.98	1.80	1.89	—.18	—.05
700	1.93	2.07	1.96	2.01	—.11	.08
701	1.93	2.07	1.93	2.00	—.14	.07
691	1.92	2.12	1 93	2.03	—.19	.11
683	1.92	1.68	1.71	1.70	.03	—.22
695	1.91	2.00	1.93	1.97	—.07	.06
684	1.90	1.95	1.89	1.92	—.06	.02
710	1.90	1.75	1.58	1.67	—.17	—.23
685	1.88	1.85	1.89	1.87	.04	—.01
694	1.87	1.95	1.85	1.90	—.10	.03
734	1.84	1.76	1.74	1.75	—.02	—.09
730	1.82	1 93	1.91	1.92	—.02	.10
689	1.79	1.78	1.81	1.80	.03	.01
688	1.78	1.93	1.80	1.86	—.13	.08
740	1.74	1.76	1.76	1.76	.00	.02
711	1.67	....	1.43	....	...	—.24
712	1.62	....	1.39	....	...	—.23
713	1.57	....	1.39	....	...	—.18

Table 2 shows the results where small individual samples of the surface six inches of soil from a virgin prairie in Lancaster county were compared. All the samples were taken with a brass tube $1\frac{3}{8}$ inches in diameter, provided with a wide collar six inches from the end. The tube was driven into the ground until the collar rested firmly on the surface of the soil. In this series the range in the percentage of humus is much narrower than in the preceding series, viz., from 2.62 to 3.70 per cent.

TABLE 2.—*Humus in small individual samples from a prairie in Lancaster county. One of the samples (No. 423) was used as standard.*

Soil No.	Gravimetric	Photometric	Difference
	Per cent	*Per cent*	*Per cent*
435	3.70	3.28	— .42
430	3.65	3.07	— .58
410	3.47	2.98	— .49
431	3.45	2.87	— .58
433	3.40	2.91	— .49
414	3.40	2.33	—1.07
429	3.40	2.96	— .44
408	3.38	3.18	— .20
434	3.35	2.79	— .56
413	3.35	2.66	— .69
421	3.35	3.08	— .27
412	3.33	2.55	— .78
428	3.30	2.89	— .41
411	3.27	2.73	— .54
407	3.20	2.83	— .37
432	3.20	2.94	— .26
422	3.18	3.30	.12
406	3.12	2.87	— .25
415	3.05	2.32	— .73
427	3.05	2.86	— .19
401	3.00	2.75	— .25
405	2.97	2.69	— .28
404	2.95	2.77	— .18
419	2.95	2.58	— .37
420	2.95	2.39	— .56
409	2.92	2.46	— .46
402	2.90	2.78	— .12
425	2.90	2.86	— .04
416	2.85	2.29	— .56
424	2.85	2.86	.01
403	2.82	2.77	— .05
426	2.70	2.87	.17
417	2.65	2.42	— .23
418	2.62	2.41	— .21

TABLE 3.—*Humus in small individual samples from a prairie in Custer county. One of the samples was used as a standard.*

Soil No.	Gravimetric	Photometric	Difference
	Per cent	*Per cent*	*Per cent*
848	1.57	1.53	—.04
849	1.77	1.68	—.09
850	1.58	1.62	.04
851	1.80	1.93	.13
852	1.49	1.53	.04
853	1.48	1.44	—.04
854	1.33	1.32	—.01
855	1.67	1.79	.12
856	2.16	2.06	—.10
857	1.43	1.62	.19
858	1.68	1.80	.12
859	1.87	2.06	.19
860	1.44	1.44	...
861	1.53	1.71	.18

Table 3 shows the results from a series of 14 individual six-inch samples taken as above described from a virgin prairie in Custer county. The agreement with the gravimetric determinations is closer in this than in Table 2, due, perhaps, to the use of a better standard.

All the samples in Table 4 were composites of surface soil taken from various parts of Chase county and of Perkins county, some from prairies, others from long cultivated fields, some from the heaviest "hard land" and others from the most sandy land which has been brought under cultivation. The concordance of the two sets of determinations is much the same as that in Table 1. With this series, however, two standards were used but both were from soils belonging to the series. The results obtained by the use of the one were practically as satisfactory as those obtained by the use of the other.

TABLE 4.—*Humus in various samples from fields in Chase county and Perkins county. Two different standards were used, viz., a, 649, and b, 574.*

Soil No.	Gravimetric	Photometric*		Difference—	
		a	*b*	Between gravimetric and *a*	Between gravimetric and *b*
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
599	1.09	1.27	1.15	.18	.06
588	1.06	1.36	1.23	.30	.27
585	1.05	1.44	1.32	.39	.27
574	1.02	1.12	1.02	.10	...
592	.99	1.21	1.12	.22	.13
590	.93	1.21	1.12	.28	.19
649	.90	.90	.92	...	.02
674	.90	.84	.77	—.06	—.13
583	89	1.29	1.10	.40	.28
587	.87	1.08	.99	.21	.12
593	.87	.83	.75	—.04	—.12
595	.83	.94	.85	.11	.02
594	.81	.90	.82	.09	.01
584	.76	.95	.87	.19	.12
589	.72	.86	.78	.14	.06
591	.72	.89	.79	.17	.07
596	.73	.95	.87	.22	.14
600	.71	.92	.86	.21	.15
612	.71	.54	.49	—.17	—.22
577	.71	.81	.73	.10	.02
586	.70	.83	.75	.13	.05
597	.69	.86	.78	.17	.09
608	.65	.54	.48	—.11	—.17
613	.65	.59	.54	—.06	—.11
578	.62	.78	.72	.16	.10
661	.66	.89	.78	.23	.12
619	.62	.39	.35	—.23	—.27
660	.64	.84	.77	.20	.13
579	.60	.66	.60	.06	.00
614	.59	.57	.52	—.02	—.07
615	.51	.57	.52	.06	.01
617	.47	.43	.39	—.04	—.08
611	.44	.48	.43	.04	—.01
618	.38	.36	.31	—.02	—.07
620	.33	.41	.37	.08	.04

* In this and the following tables the colorimetric determinations are included in the column headed "photometric."

In Table 5 are given the data on a series of samples ranging in depth from one inch to four feet below the surface. These were taken from the walls of a trench dug for the purpose. The agreement is fairly satisfactory, except thru a layer of about

six inches, located between the eleventh and the sixteenth inches, where the photometric readings indicated a much higher percentage of humus than was afterwards found by the gravimetric. The concordance of the results in the case of the samples of subsoil is striking.

TABLE 5.—*Humus from different depths in a trench in Perkins county. For the standard a bulk sample of surface six inches of soil from the same prairie was used.*

Soil No.	Depth	Gravimetric	Photometric	Difference
		Per cent	*Per cent*	*Per cent*
1150	1st inch	.92	.57	—.35
1151	2d "	.64	.69	.05
1152	3d "	66	.59	—.07
1153	4th "	.65	.54	—.11
1154	5th "	.65	.52	—.13
1155	6th "	.58	.57	—.01
1156	7th "	.65	.63	—.02
1157	8th "	.54	.60	.06
1158	9th "	.44	.56	.12
1159	10th "	.61	.69	.08
1160	11th "	.60	.95	.35
1161	12th "	.71	1.14	.43
1162	13th "	.93	1.60	.67
1163	14th "	1.06	1.72	.66
1164	15th "	.91	1.72	.81
1165	16th "	.84	1.47	.63
1166	17th "	1.07	1.06	—.01
1167	18th "	.53	.87	.34
1168	19th "	.42	.64	.22
1169	20th "	.44	.59	.15
1170	21st "	.35	.53	.18
1171	22d "	.34	.50	.16
1172	23d "	.36	.41	.05
1173	24th "	.32	.39	.07
1174	25-27 "	.26	.32	.06
1175	28-30 "	.15	.21	.06
1176	31-33 "	.09	.16	.07
1177	34-36 "	.09	.11	.02
1178	37-39 "	.06	.05	—.01
1179	40-42 "	.06	.03	—.03
1180	43-45 "	.07	.04	—.03
1181	46-48 "	.05	.04	—.01

The data in Table 6 are from composite samples of the surface foot of soil from various plots and fields on or near the Experi-

ment Station Farm. Two standards were used with part of the series. The one, *"a"*, was one of the two used with the series given in Table 4, being from the western part of Nebraska. The other, *"b"*, was a composite extract made by combining equal volumes of the extracts from four of the samples under examination, viz., 901, 902, 914, and 915, and determining gravimetrically the humus content. The second standard gave results agreeing closely with those obtained by the gravimetric determination, but the first gave, with part of the samples, results that were considerably too high.

TABLE 6.—*Humus in the surface foot of soil in various plots on the Experiment Station Farm.*

Soil No.	Gravimetric	Photometric		Difference between—	
		a W. Nebr. standard 649	*b* E. Nebr. standard	Gravimetric and photometric *a*	Gravimetric and photometric *b*
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
902	2.68	3.55	2.83	.87	.15
903	2.44	3.29	2.62	.85	.18
901	2.29	2.86	2.28	.57	—.01
916	1.91	2.39	1.91	.48	...
914	1.85	2.29	1.82	.44	—.03
912	1.89	1.83	....	—.06	...
917	1.88	2.29	1.82	.41	—.06
915	1.80	2.39	1.91	.49	.11
913	1.77	2.01	....	.24	...
908	1.32	1.37	....	.05	...
910	1.31	1.49	....	.18	...
911	1.24	1.28	....	.04	...
909	1.23	1.08	....	—.15	...
905	1.12	1.07	.85	—.05	—.37
907	.99	.75	....	—.24	...
904	.92	.72	.85	—.20	—.07

In order to determine the availability of the photometric method for determinations of the so-called humus as obtained by the "official" method, 20 samples taken from a bulk sample of the surface six inches of a prairie in Perkins county were freed of lime and magnesia, as usual, and, after removing the excess of acid, half of the samples, selected at random, were

treated by the "official" method and the other half by the Hilgard method. The solutions obtained by the latter method were diluted to 500 c.c. When the solutions had all been prepared, the humus was determined, first by the photometric method and then by the gravimetric method. The results are given in Table 7, in which the determinations are reported in the order of the content of humus ash. The standard used was a humus extract obtained from the same soil by the Hilgard method.

TABLE 7.—*Comparison of the Hilgard method with the "official" method.*

	Gravimetric methods				Photometric method	
	Humus		Humus ash		Humus	
	Official	Hilgard	Official	Hilgard	Official	Hilgard
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1.....	1.97	.70	7.20	.32	1.64	.88
2.....	1.92	.89	7.01	.29	1.80	.89
3.....	1.79	.75	6.21	.26	1.95	.80
4.....	1.90	.83	6.10	.26	1.70	.87
5.....	1.65	.85	5.63	.26	2.53	.80
6.....	1.68	.78	5.58	.26	1.61	.89
7.....	1.73	.89	5.36	.25	1.75	.89
8.....	1.71	1 01	4.80	.21	1.64	.87
9.....	1.43	.77	3.84	.21	2.09	.80
10.....	1.45	.71	3.46	.20	1.65	.77
Average	1.72	.82	5.52	.25	1.84	.85

While the amount of humus found by the "official" method increased in general with the amount of humus ash, this was not the case with the data obtained by the photometric determination of the same solutions. While the average of the results obtained by the photometric method agreed very well with the average of those obtained by the gravimetric method, this was due to the comparatively large number of determinations made. The individual determinations varied from 1.64 to 2.53 per cent, whereas the gravimetric determinations varied only from 1.43 to 1.97 per cent.

The best conditions for the use of the photometric method require, first, that the solution be kept as concentrated as is possible without too great inconvenience in securing complete extraction, and second, that a typical soil from the same region be used in the preparation of the standard.

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THE MINERAL CONSTITUENTS OF SOME SOILS OF THE EASTERN NEBRASKA LOESS

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The soils the analyses of which are reported in the following pages were taken from what are to be regarded as strictly loess areas. They belong to three fairly distinct types. The one having by far the most extensive distribution is represented by the samples reported in Tables 1, 4, 5, and 6*b*. In this type, which occurs on the high, level, or gently rolling lands, the surface is being gradually lowered by erosion. On it there has probably been little deposition of soil by either wind or water. A second type, having a limited distribution, is represented by the samples reported in Tables 2, 6*a*, and 6*c*. This is the lowland soil which occurs adjacent to the preceding. It is found along creeks, "runs," and still shallower depressions thru which water flows after heavy rains. Wherever it is protected by a dense covering of vegetation it is still being added to and in some cases an addition of transported soil occurs even in the case of bare, cultivated fields. The material deposited on it is derived either entirely, or chiefly, from the erosion of the surface soil of the preceding type. The third type of loess soil is represented in Tables 3, 7, and 8. This lies in a broad plain which locally is known as a valley, it having higher lands on both sides It is at no great distance from the edge of the great area of Nebraska sand hills. This type of soil gives no evidence of having in recent times received an appreciable addition of soil by deposition from water. It was, evidently, laid down under conditions quite different from those prevailing in the case of the first type. The soils belonging to the first two types analyzed are all from Lancaster county, of which the Bureau of Soils of the United States Department of Agriculture has recently made a

survey.[1] On the Bureau of Soils map the two types are shown as Marshall Silt Loam and as Wabash Silt Loam, respectively.

The samples from the first two types were taken in 1907 and those from the other in 1908 in connection with a study of the changes in the amount of nitrogen, humus, and total organic matter that have been induced by cultivation.[2] In the summer of 1908, as a preliminary investigation of the mineral constituents of the loess soils of Nebraska, the acid-soluble potash and soda, and incidentally the acid-insoluble matter, were determined by R. A. Gortner, and the acid-soluble phosphoric acid by W. D. Bonner and C. E. Vail. The portions of the solutions remaining after the determination of the potash in duplicate were saved in glass flasks (not Jena). During the following winter the junior author determined the lime in part of the solutions and still later the rest of the mineral constituents. Where the duplicate determinations were not concordant and all of the "solutions A" had been used, the results are not reported in the tables. The preparation of the "solutions A" is an operation involving much time, and only a very small amount of money was available to meet the expenses of the work. The large number of analyses reported would not have been possible with the small sum of money available had it not been that the junior author was a graduate student working on his thesis. The tables below are part of the data finally presented in his thesis for the Master's degree.

METHODS OF SAMPLING

The samples to a depth of six inches were secured by means of a brass tube 1⅜ inches in diameter and provided with a wide brass collar 6 inches from the end. The tube was forced into the ground until the collar rested firmly on the surface. Also, for samples of the second six inches of soil the tube was used after removing the first six inches of soil by means of a spade. The samples analyzed were composites of from five to ten indi-

vidual cores taken with the tube. To obtain inch sections for analysis, cores obtained as above were subdivided.

In the case of the first foot of soil from the first prairie sampled, the surface six-inch cores were divided into five equal sections as were also the second six-inch cores. Thus, the first, fifth, sixth, and tenth sections correspond to the first, sixth, seventh, and twelfth sections from the other two prairies.

For samples of soil from below the first foot two augers were used, the one of $1\frac{3}{4}$ inch and the other of 1 inch diameter. The larger auger was used to remove the first foot of soil, after which the smaller was employed to obtain the sample of the second foot. The larger auger was next used to enlarge the hole to the bottom of the second foot. Then by means of the small auger the third foot samples were taken. This process was continued for the still lower portions of the soil. If a single auger had been used the samples from below the first foot would have been more or less affected by material from nearer the surface adhering to them.

The number of individual samples used in making the composite samples analyzed was too small to be satisfactory for a study of the acid soluble mineral components, altho satisfactory for the purpose for which the samples were taken. For this reason the number of individual samples used in making the composites becomes important and is indicated below in the description of the different tables.

METHODS OF ANALYSIS

The determinations of potash, phosphoric acid, and lime were made by the Hilgard methods for the acid digestion of soils. For phosphoric acid the ignited soil was digested with strong nitric acid for two days on the steam bath. For the other constituents the methods of the A. O. A. C.[3] were used after the so called "solution A" had been prepared by the digestion of the soil for 120 hours with hydrochloric acid (instead of for 10 hours, the time of digestion adopted by the A. O. A. C.) and the removal of the dissolved silica.

THE SURFACE FOOT OF VIRGIN PRAIRIES

In the case of three virgin pariries ten cores taken to a depth of one foot were subdivided, in the case of the first into ten and in that of the other two into twelve parts. The first prairie (Table 1), which is less than half a mile from the Nebraska Experiment Station farm, has since 1889 formed a part of the campus of the Nebraska Wesleyan University. The portion from which the samples were taken has since that time been mown annually for hay; during the rest of the year it has been little visited except by children in search of wild flowers. Previous to 1889 it had formed part of a large pasture. It is typical of the virgin upland prairie of eastern Nebraska. The loess varies from 15 to 20 feet in depth, it being underlaid with boulder clay.

The samples reported in Table 2 are from the lower, level portion of what is known as Peck's Grove, which is situated a few hundred yards south of the Experiment Station. Some thirty or forty years ago cottonwood trees were planted in the prairie and since then the soil has been left undisturbed. The lower portion of the grove, where the samples were taken, is flooded after torrential rains.

The third prairie (Table 3) is near Elgin on the farm of the Hon. George Coupland, who has used it as a pasture for over thirty years. Previous to that the whole farm was part of the unfenced public domain.

There are no marked differences in the mineral composition of the different inch sections except that the surface inch is distinctly higher in volatile matter than the lower sections.

THE FIRST SIX FEET OF VIRGIN PRAIRIES

Table 4 gives the data on the samples from the prairie on the Nebraska Wesleyan University campus. The samples were composites from two borings. The samples reported in Table 5 are from seven borings on level upland fields just south of the

Experiment Station Farm. The data in Table 6 are from the Experiment Station Farm pasture thru which passes the water course known as Dead Man's Run. The lowland portion (6*a*) is inundated at times of very high water, after which a heavy deposit of soil is to be found covering the surface. The grass soon grows above this, however, and at the end of a few weeks there is little evidence of the high water left. In 6*c* is given the analysis of a composite of a large number of samples collected just after an overflow of Dead Man's Run in April, 1908. The soils reported in Table 6*a* are of the same type as those reported in Table 2. The black soil extends to a depth of from 3 to 5 feet. The samples analyzed were composites from five borings. The upland portion of the pasture, from three borings in which the samples reported in 6*b* were taken, slopes to the north and east. It receives no deposit from high water, but on the contrary it is exposed to considerable erosion. The samples reported in Table 7 are composites from two borings from the same prairie as those reported in Table 3. Those in Table 8 are from the farm of Mr. A. Perry, four miles north of Elgin. They also are composites from two borings.

The set of samples reported in Table 9 is from a single boring near the residence of Mr. Coupland. At this point the loess sheet has a thickness of about 36 feet.

THE SURFACE SOIL FROM ADJACENT FIELDS AND PLOTS

In Table 10 the composition of samples from adjacent fields and plots on the Experiment Station Farm is reported. For the samples of the surface six inches of soil six cores were used and for those of the first foot of soil four borings were made. Table 11 gives similar data for the fields on the farms of Mr. Coupland and his neighbors. The number of individual samples used for the different composites in the case of these is indicated in the table.

The data in the tables do not show any connection between

the crop history of the fields and the present mineral composition of their soils. The worse a field has been eroded by wind and water, the higher is the content of potash and phosphoric acid found to be, for the reason that the surface soil is poorer in these constituents than the subsoil. The differences in the content of phosphoric acid shown in Table 10 (.05, .06, .07) are less than the experimental error. The differences in potash are in some cases less and in others much greater than the experimental error. As an illustration of this, in Table 12 there are shown the percentages of potash and soda found in the case of soil No. 1509. Samples of this were analyzed on eleven different days in the course of the series of analyses, each analysis being conducted as tho it were of a distinct soil sample. Thus, differences obtained upon different days may be considered those which are to be attributed to the method of analysis. Greater differences when found are to be considered as due to actual differences in the samples.

TABLE 1.—*Surface foot of soil from prairie at Lincoln (Nebraska Wesleyan University campus).*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
516	First tenth.....	77.44	.55	.27	.40	.55	3.24	5.90	.09	.04	11.26	100.07
517	Second tenth....	78.77	.57	.17	.47	.43	3.08	6.78	.08	.04	9.60	99.99
518	Third tenth	78.79	.60	.24	.48	.40	3.04	7.06	.09	.04	9.12	99.86
519	Fourth tenth....	78.65	.64	.44	.51	.46	3.04	7.76	.09	.04	9.04	100.67
520	Fifth tenth.....	78.52	.63	.38	.52	.63	3.12	7.37	.11	.06	8.34	99.74
521	Sixth tenth.....	79.67	.64	.29	.55	.5,	3.44	6.90	.08	.05	8.42	100.63
522	Seventh tenth...	79.28	.70	.25	.50	.62	3.28	7.56	.07	.06	8.18	100.41
523	Eighth tenth...	79.45	.68	.16	.47	.57	3.44	7.92	.08	.05	8.09	101.01
524	Ninth tenth.....	80.24	.64	.30	.44	.65	3.12	7.60	.08	.05	7.78	100.90
525	Tenth tenth.....	79.39	.69	.27	.42	.60	3.72	7.88	.09	.06	7.40	100.52
	Average.....	79.05	.63	.28	.48	.55	3.25	7.27	.09	.05	8.72	100.37

TABLE 2.—*Surface foot of soil from prairie at Lincoln (Peck's Grove).*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1469	First inch.....	73.63	.88	.43	.70	.61	3.74	7.17	.07	.06	13.25	100.27
1470	Second inch.....	78.44	.61	.13	.95	.73	2.47	5.81	...	.07	10.54	.....
1471	Third inch.....	79.88	.67	.26	.88	.49	2.41	6.02	.07	.06	8.60	99.34
1472	Fourth inch.....	80.76	.65	.11	.85	.49	3.06	5.34	.07	.05	7.90	99.28
1473	Fifth inch.....	83.13	.56	.18	.75	.63	2.78	5.91	.07	.05	7.23	101.29
1474	Sixth inch.....	81.94	.68	.15	.73	.56	2.89	5.42	.06	.05	6.91	99.39
1475	Seventh inch....	82.96	.60	.18	.75	.60	3.14	4.97	.06	.06	6.79	100.11
1476	Eighth inch.....	.....	.57	.21	.79	.54	3.14	5.07	.06	.05	6.58	.....
1477	Ninth inch	83.18	.62	.23	.80	.55	3.24	5.21	.09	.05	6.35	100.32
1478	Tenth inch.....	.....	.71	.15	.65	.50	2.47	5.81	.09	.05	5.83	.....
1479	Eleventh inch...	83.24	.63	.13	.72	...	2.15	6.26	.06	.06	6.03	.....
1480	Twelfth inch.....	82.54	.68	.22	.75	.49	2.41	6.12	.05	.07	5.74	99.07
	Average.....	80.97	.65	.18	.78	.56	2.82	5.77	.06	.06	7.63	99.48

TABLE 3.- *Surface foot of soil from prairie near Elgin, Antelope County.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1610	First inch.....	84.50	.49	.13	.35	.49	2.52	4.43	.07	.04	8.00	100.93
1611	Second inch.....	84.71	.40	.08	.50	.51	1.88	4.11	.08	.04	7.26	99.57
1612	Third inch.....	85.10	.44	.07	.60	.63	2.40	4.73	.08	.05	7.80	101.90
1613	Fourth inch.....	85.81	...	...	.62	.82	2.96	5.14	.06	.04	7.89	.....
1614	Fifth inch.....	84.34	.45	.08	.41	.50	2.80	4.93	.06	.05	7.88	101.50
1615	Sixth inch.....	85 21	.41	.12	.30	...	....	....	.09	.05	7.78	.....
1616	Seventh inch....	82 25	...	...	.39	.67	....	....	...	.04	7 51	.....
1617	Eighth inch.....	84.65	.53	.10	.40	.60	2.96	5 59	.08	.04	7.24	102 19
1618	Ninth inch.....	84.87	.49	.13	.34	.63	3.00	4.95	.06	.06	7.01	101 54
1619	Tenth inch.....	84.91	.50	.10	.28	.69	2.52	5.83	.07	.07	6.80	101.75
1620	Eleventh inch...	85.61	.50	.12	.30	...	2 76	5.12	.05	.04	6.59	101.29
1621	Twelfth inch....	85.38	.48	.14	.41	.47	2.76	4.91	.06	.05	6.78	100.44
	Average	84.68	.47	.11	.41	.56	2.66	4.97	.07	.04	7.38	101.35

TABLE 4.—*First six feet of soil from prairie at Lincoln (Nebraska Wesleyan University campus).*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
516-525	First foot.....	79.05	.63	.28	.48	.55	3.25	7.27	.09	.05	8.72	100.37
528	Second foot....	73.50	.77	.32	.70	1.26	4.61	10.87	.07	.04	8.02	100.16
529	Third foot	75.13	.91	.21	1.07	1.03	4.76	10.76	.10	.05	6.81	100.83
530	Fourth foot ...	76.58	1.01	.13	1.66	....	4.28	9.83	.14	.06	6.29	.....
531	Fifth foot	77.45	....	...	.86	....	....	.....	.14	.05	5.62	.....
532	Sixth foot.....	79.73	....	...	.84	....	....	.....	.14	.04	5.55	.....

TABLE 5.- *Composite samples from fields adjacent to the Experiment Station Farm, Lincoln.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1544	First foot.....	78.46	.69	.19	.68	.78	3.71	8.84	.05	.07	7.87	101.45
1545	Second foot.....	75.68	.94	.15	1.03	1.25	4.24	.....	.06	.09	8.25	.....
1546	Third foot.....	76.51	.97	.26	1.20	1.19	4.64	10.71	.11	.06	5.83	101.48
1547	Fourth foot.....	77.52	.97	...	1.54	1.35	3.88	10.25	.13	.06	4.65	101.35
1548	Fifth foot.....	77.99	.96	...	1.51	1.03	4.32	.....	.15	.04	4 21	100.56
1549	Sixth foot.....	.....	.97	...	1.07	1.06	4.27	.....	.13	.04	5.12	.....
	Average.....	77 23	.91	...	1.17	1.11	4.18	.....	.10	.06	5.99	.....

TABLE 6.—*Pasture field on Experiment Station Farm, Lincoln.*

a. LOWLAND PORTION.

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1462	First foot...	78.60	.73	.27	.74	.77	3.21	7.24	.07	.07	8.74	100.44
1463	Second foot.....	81.17	.61	.24	.84	.55	3.28	6.18	.10	.05	7.46	100.48
1464	Third foot	79.82	.75	.24	.83	.59	3.82	7.68	.10	.05	6.58	100.46
1465	Fourth foot	84.39	.73	.10	.51	...	3.31	7.13	.09	...	4.25	100.51
1466	Fifth foot.....	86.71	.81	.40	.70	.82	....	....	.09	.06	...	.....
1467	Sixth foot.	79.77	.86	.23	.91	...	3.98	7.86	.09	.05	5.08	.....
	Average.....	81.74	.75	.25	.76	...	3.51	7.40	.09	.06	6.43	.....

b. UPLAND PORTION.

1459	First foot.....	79.00	.76	.18	.40	.64	3.42	7.93	.08	.07	8.46	100.94
1460	Second foot.....	75.08	1.04	.21	.63	1.09	4.10	10.10	...	.07	7.42	.....
1461	Third foot.....	77.00	.87	.29	.98	1.31	4.66	7.08	...	.07	5.64	.....
	Average.....	77.03	.89	.23	.67	1.01	4.06	8.37	..	.07	7.17	.....

c. FLOOD DEPOSIT.

1564	Flood deposit...	80.29	.72	.32	.57	.87	...	.....	.06	.05	7.02	.....

TABLE 7.—*First six feet of soil from prairie in Antelope County.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
	*First foot.....	84.68	.47	.11	.41	.56	2.66	4.97	.07	.04	7.38	101.35
1625	Second foot.....	86.11	.47	.16	.66	. .	2.65	5.60	.06	.05	4.16	100.01
1626	Third foot.....	83.46	...	...	.58	.68	2.80	7.23	.07	.06	4.09	.....
1627	Fourth foot.....	87.69	.48	.15	.84	.57	2.60	6.27	.07	.06	3.25	101.98
1628	Fifth foot.....	86 07	.47	.15	.50	.64	2.95	5.34	.09	...	4.21	100.42
1629	Sixth foot..	88.14	.50	.14	.50	.65	2.75	4.72	.08	.07	3.62	101.86
Average		86.03	.48	.14	.58	.62	2.73	5.70	.07	.06	4.45	100.86

* Average of 1610 to 1621.

TABLE 8.—*First six feet of soil from prairie on farm of A. Perry, Antelope County*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1658	First foot.....	82.71	.57	.19	.96	.76	3.00	5 51	.08	...	7.38	100.40
1659	Second foot.....	80.80	.58	.22	4.04	...	3.40	6.97	.11	.05	....	.....
1660	Third and fourth foot.	77.09	.63	.12	4.44	...	3 00	5.96	.15	.04	7.79	99.22
1661	Fifth foot.	78.00	.61	.17	4.21	...	3 20	6.37	.14	.04	...	.....
1662	Sixth foot.....	71.37	.62	17	4.77	...	3.40	6.11	.14	.04	....	.....
	Average..... ...	78.64	.61	.16	3.61	...	3.16	6.14	.13	.04	....	.....

TABLE 9.—*Deep subsoil from a field in Antelope County.*

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1707	7 to 9 ft.....	76.23	1.11	.33	3.04	1.43	3.88	8 82	.14	.08	....	....
1711	10 to 12 ft.....	75.50	1.07	.32	2.82	1.38	3.92	9 25	.14	.07	....	....
1715	12 to 14 ft.....	75.31	1.23	.38	2 64	....	3.76	8.63	.15	.04	....	....
1719	16 to 18 ft.....	74.96	1.22	.51	2.88	1.44	4.10	8.80	.15	.06	....	....
1722	19 to 20 ft.....	75.42	1.21	.28	2.90	....	....	....	.15	...	....	....

TABLE 10.—*Surface soil from fields on or near the Experiment Station farm, Lincoln.*

FIRST SIX INCHES.

Soil No.		Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
536	Lowland grove..	80.66	.62	.20	.70	.61	....	....	.07	...	8.72	.....
535	Lowland pasture.	79.08	.75	.23	.62	.72	4.08	4.70	.06	...	9.76	.....
534	Upland pasture..	78.49	.77	.21	.55	.74	3.18	6.93	.06	.05	9.08	100.04
1541	Upland alfalfa..	81.41	.77	...	...	...	....	....	.07	.06	7.14	.....
1542	Upland orchard..	78.67	.92	.20	.54	.83	3.36	....	.08	.06	7.11	.....
1543	Upland alfalfa (2)	80.45	.69	.12	.52	.75	3.48	7.20	.07	.05	7.58	100.91
1506	Upland grass plot	79.65	.87	.28	...	.60	3.34	6.82	...	.06	9.01	.....
1507	Upland long cultivated field....	79.92	.75	.23	.51	.64	3.26	5.99	...	.06	8.66	100.02

FIRST TWELVE INCHES.

903	Lowland grove...	82.02	.63	.19	.66	.56	2.40	5.70	.07	.06	8.23	100.52
902	Lowland pasture.	80.73	.63	.18	.53	.59	2.97	6.62	.07	.07	9.15	101.54
901	Upland pasture..	78.80	.78	.14	.54	.77	3.60	6.74	.07	.05	8.72	100.21
1551	Upland alfalfa...	77.55	...	...	.53	.74			...	.07	7.59	.....
1552	Upland orchard..	79.84	.76	...	.51	.76	3.48	7.42	.07	.05	7.33	100.22
1553	Upland alfalfa (2)	79.97	.82	...	.55	.80	3 20	7.17	.06	.05	7.40	100.02
1505	Upland grass plot	80.91	.74	...	.60	.55	2.85	7.80	...	.05	8.19	.....
1508	Upland long cultivated field...	80.64	.74	...	.55	.56	3.00	6.72	...	.05	8.06	.....

TABLE 11.—*Surface six-inch samples from various fields on the farms of Mr. George Coupland and his neighbors.*

Soil No.	Insoluble matter	Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron oxide Fe_2O_3	Alumina Al_2O_3	Phosphoric acid P_2O_5	Sulphuric acid SO_3	Volatile matter	Total
1622†	82.63	.54	.12	.48	.61	...	...	.08	.06	7.79	.....
1631†	88.00	.43	.16	.43	.45	2.24	4.21	.06	. .	4.12	100.10
1632†	85.26	.45	.11	.51	.50	....	....	.06	.03	6.41	.....
1633†	86.69	.41	.09	.50	.45	...	....	.06	.04	5.31	.....
1634†	86.59	.45	.14	.50	.40	2.40	4.88	.06	.06	5.13	100.61
1635†	84.93	.56	.12	.49	48	....	...	.07	.04	5.59	.....
1636†	84.23	.62	.12	.53	.52	2.85	5.69	.06	.04	5.95	100.61
1637†	84.35	.51	.12	.44	.60	2.87	5.32	.07	.05	7.05	101.38
1638*	85.00	.46	.14	.47	.62	2.95	5.00	.06	.05	6.69	101.44
1639*	84.50	.51	.12	.46	.46	3.10	5.56	.07	.06	6.86	101.70
1644†	84.81	.50	.16	.48	.66	3.05	5.02	.08	.04	5.95	100.75
1645†	82.06	.59	.16	.47	...	3.05	....	.08	.05	7.96	.....
1646†	83.09	.56	.20	.62	.78	3.10	6.10	.08	.04	7.16	101.73
1647†	90.40	.33	.13	.54	.38	2.45	2.31	.08	.04	4.89	101.55
1648†	86.67	.43	.14	.49	.58	2.80	3.37	.07	.05	5.75	100.35
1649‡	84.35	.51	.16	.59	.43	2.60	4.65	.07	.06	7.58	100.99
1650‡	88.41	.40	.11	.53	.42	2.20	3.94	.06	.05	5.10	101.22
1651‡	87.70	.42	.16	.44	.37	3.00	4.70	.06	.05	5.28	100.18
1652‡	84.54	.51	.15	.44	.40	3.47	5.07	.08	.05	6.94	101.65
1653‡	87.70	.40	.13	.45	.52	....	...	.08	.05	5.55	.....
1654‡	86.45	.41	.16	.45	.47	2.50	4.05	.06	.07	6.00	100.62
1655†	83.75	.52	.12	.46	.60	3.00	4.50	.08	.05	7.75	100.83
1656†	85.59	.46	.15	.39	...	3.00	4.85	.09	.04	....	.....
1657†	84.83	.55	.18	.36	...	....	....	.08	...	6.61	.....

*Nos. 1638 and 1639 are composites of four one-foot samples corresponding to Nos. 1637 and 1636 respectively.

†The sample is a composite of 10 individual samples.

‡The sample is a composite of 6 individual samples.

TABLE 12.—*Analysis of the same soil on different days.*

No. of analysis	Potash K_2O	Soda Na_2O
1	.90	.29
2	.87	.32
3	.88	.35
4	.89	.39
5	.91	.35
6	.87	.29
7	.86	.29
8	.91	.31
9	.88	.29
10	.91	.27
11	.91	.27
Average	.89	.31
Highest	.91	.39
Lowest	.87	.27

From these analyses of surface soils it is evident that it is futile to attempt to find differences in the amount of the mineral constituents which have been caused by cultivation, unless the samples analyzed are composites of at least a very large number of individual samples.

An exhaustive study of the chemical composition of the soils of the loess prairies of Nebraska is now being made at this Experiment Station, the composite samples used being composed of from 50 to 100 individual samples.

REFERENCES

1. Soil Survey of Lancaster Co., Nebraska. Bur. of Soils (1908).
2. Alway: Changes in the Composition of the Loess Soils of Nebraska Caused by Cultivation, Bul. 111, Nebr. Exp. Sta. (1909).
3. Bul. 107, revised, Bur. of Chem. (1908).

ON THE SAMPLING OF PRAIRIE SOILS

By F. J. Alway and R. S. Trumbull

The surface soil of cultivated fields tends to become uniform on account of the constant stirring and mixing to which it is subjected in the course of tillage operations. In the case of the surface soil of prairies there is no such action tending to produce uniformity. Slight differences in texture tend to produce marked differences in the chemical composition. This is well illustrated in the case of some prairie soils which we have described elsewhere.[1] In order that comparisons of any value may be made of the composition of surface soils of prairies with those from cultivated fields, methods of sampling must be used which give samples that are really representative. In some cases it seems almost impossible to obtain an entirely satisfactory sample of the prairie soil for such purposes of comparison. First among the things to be considered in this connection are the number of individual samples that must be taken in order to make a representative composite and the influence upon the composition of the sample of slight differences in the depth to which it is taken. As preliminary to the study of the surface soils of Nebraska prairies, the greater part of the data given in the following tables was collected.

METHODS OF SAMPLING

The samples to a depth of 6 inches were secured by means of a brass tube $1\frac{3}{8}$ inches in diameter and provided with a wide brass collar 6 inches from the end. The tube was forced into the ground by the operator standing on it or jumping upon it until the collar rested firmly upon the surface. For samples of the second six inches of soil, the same tube was used after removing the first six inches by means of a spade.

The individual samples were taken at certain intervals, any distinct irregularities on the surface, such as paths, trails, mounds, etc., being avoided. Usually the members of a series of samples were in a straight line across the prairie. The vegetation was clipped off level with the surface but all plant residues as well as roots, insects, etc., were treated as an integral part of the soil, for the reason that these carry nitrogen in its most readily available form.

METHODS OF ANALYSIS

The nitrogen was determined by the ordinary Kjeldahl method and the humus by the Hilgard method, the ammonia being applied continuously until the washings were colorless. This, as has been shown previously,[2] may leave a little of the humus unextracted, but with the soil types in question this residue would be insignificant, the percentage of unextracted humus being less than the differences between duplicate determinations of the same soil. This has been discussed in detail in Bulletin 115 of the Nebraska Experiment Station, the data being given in Tables II and III of that bulletin, and the soils reported as Nos. I, II and III are representative of the three types of soil dealt with in the following pages. The percentages of humus ash, where determined, are given as evidence of the reliability of the humus determinations.

In the case of different samples where the weight of the cores is reported the soil was dried at 110° C. before weighing.

SAMPLES FROM PRAIRIES ON THE LOESS AREA

Lancaster County.—The series of samples reported in Table 1 was taken in August, 1907, from a portion of the campus of the Nebraska Wesleyan University, described elsewhere in this Report. In the case of four groups of five samples each, the cores were taken only two inches apart, the groups being at intervals of 60 yards. The other samples were taken at intervals of 30 feet.

The humus contained in the 35 individual samples ranged from 2.65 per cent to 3.70 per cent and the nitrogen from 0.250 per cent to 0.317 per cent. Thus the differences between the extremes in the case of both constituents amount to over 30 per cent of the quantity present in the sample with the smallest amount. Even in the case of the groups of five samples taken close together the differences between extremes amount to as high as 15 per cent. Thus the differences found between individual samples taken close together are as great as those found between the soil of long-cultivated fields and that of the adjacent virgin prairies.[3] That the differences become less when composites of a number of individual samples are used is shown in Table 2. By using a composite of five samples the extremes would have become, for humus, 3.42 per cent and 2.81 per cent, and for nitrogen, 0.304 per cent and 0.276 per cent, the differences becoming half or less of what they were found to be when the individual samples were compared. By combining from 10 to 15 individual samples as composites for analysis, the extremes would have been, for humus, 3.05 and 3.34 per cent, and for nitrogen 0.281 and 0.297 per cent, the differences being half as great as with the composites of five. By increasing the number of individual samples used for the composites to 20, the differences between the different composites would have become less than the experimental error of analysis. The greatest variations are in the humus content and it is to be observed that the humus content does not rise and fall with that of the nitrogen when only individual samples are compared. This is to be attributed to the varying amounts of roots, unhumified plant residues, insects, etc., in the individual samples. These parts of the samples, while rich in nitrogen, contain no humus.

Considering the averages of all 35 samples as the actual amount of humus and nitrogen present in a strictly representative sample from the prairie, it will be seen that using the data from the analysis of composites of five individual samples the

maximum error would have been approximately ten per cent in the case of humus and approximately five per cent in the case of nitrogen.

TABLE 1.—*Composition of individual samples from the prairie on Nebraska Wesleyan University campus.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of 6 inch sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1	.....	3.00	.275	134.1	10.9
2	2 inches.....	2.90	.276	132.9	10.5
3	2 inches.....	2.82	.283	120.9	10.0
4	2 inches.....	2.95	.277	117.6	10.6
5	2 inches.....	2.97	.268	126.7	11.1
6	30 feet	3.12	.287	133.0	10.8
7	30 feet	3.20	.288	121.2	11.1
8	30 feet	3.37	.301	118.8	11.2
9	30 feet	2.92	.250	132.7	11.7
10	30 feet	3.47	.306	128.2	11.3
11	30 feet	3.27	.294	116.7	11.1
12	2 inches.....	3.33	.293	115.7	11 4
13	2 inches.....	3.35	.312	113.7	10.7
14	2 inches.....	3.40	.313	113.1	10.9
15	2 inches.....	3.05	.306	132 3	10.0
16	30 feet	2.85	.278	127 5	10.3
17	30 feet	2.65	.317	125.3	8.4
18	30 feet	2.67	.278	127.0	9.6
19	30 feet	2.95	.303	131.8	9.7
20	30 feet	2.95	.279	124.9	10.6
21	30 feet	3.35	.299	108.4	11.2
22	2 inches.....	3.17	.291	125.1	10.9
23	2 inches.....	3.10	.313	113.7	9.9
24	2 inches.....	2.85	.296	122.1	9.6
25	2 inches.....	2.90	.278	125.7	10.4
26	30 feet	2.90	.270	122.6	10.7
27	30 feet	3.05	.286	112.6	10.7
28	30 feet	3.30	.289	108.7	11.4
29	30 feet	3.40	.291	129.7	11.7
30	30 feet	3.65	.302	114.6	12.1
31	30 feet	3.45	.298	132.4	11.6
32	2 inches.....	3.20	.285	124.3	11.2
33	2 inches.....	3.40	.306	124.1	11 1
34	2 inches.....	3.35	.279	127.7	12.0
35	2 inches.....	3.70	.291	121.9	12.7
	Average of all....	3.14	.290	124.2	10.8

TABLE 2.—*The concordance of results obtained by increasing the number of samples used in making a composite.*

	Weight	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
First five	134.4	2.93	0.276	10.6
Second five	126.8	3.22	0.286	11.3
Third five	118.3	3.28	0.304	10.8
Fourth five	127.3	2.81	0.291	9.7
Fifth five	119.0	3.07	0.295	10.4
Sixth five	117.6	3.26	0.288	11.3
Seventh five	126.1	3.42	0.292	11.7
First ten	130.6	3.08	0.281	10.9
Intermediate fifteen	121.5	3.05	0.297	10.3
Last ten	121.9	3.34	0.290	11.5
First twenty	126.7	3.06	0.289	10.6
Last twenty	122.5	3.14	0.291	10.8
Average of all	124.2	3.14	0.290	10.8

The humus and nitrogen contained in the surface soil of virgin prairies decreases rapidly from the surface downward, as is shown in Table 3. Hence, if, in sampling, the samples were more compacted, as by a heavy man jumping upon the sampler to force it into the ground or by the surface having been trodden by the feet of pasturing animals, a deeper section would unconsciously be taken. Also, the samples taken early in the spring or after a heavy rain might be deeper than usual. Such differences would be revealed by the weight of the dry samples, the lighter the sample the shallower the penetration of the sampler having actually been. The heavier the individual samples the lower the nitrogen and humus would be expected to be. To show the actual relation between the weight of the core and its composition, the data are arranged in Table 4 in the order of the weights of the individual cores. It will be seen that when individual samples are compared there is no direct relation between the weight and the composition of the sample. When groups of

five or ten are compared, there is, however, a decrease in the content of nitrogen accompanying an increase in the weight of the sample.

TABLE 3.—*The average content of nitrogen and humus at different depths in the surface foot of prairies on the Nebraska loess.**

	Nitrogen	Humus
	Per cent	*Per cent*
First inch	.360	3.64
Second inch	.292	3.01
Third inch	.247	2.88
Fourth inch	.222	2.41
Fifth inch	.209	2.35
Sixth inch	.199	2.40
Seventh inch	.188	2.23
Eighth inch	.179	2.27
Ninth inch	.170	2.04
Tenth inch	.163	1.79
Eleventh inch	.155	1.91
Twelfth inch	.151	1.48

* From Tables VIII and XII, Bulletin 111, Nebraska Experiment Station.

TABLE 4.—*Data in Table 1 rearranged to show the relation between the weights of the samples and their composition.*

Sample No.	Weight of six-inch sample	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
21	108.4	3.35	.299	11.2
28	108.7	3.30	.289	11.4
27	112.6	3.05	.286	10.7
14	113.1	3.40	.313	10 9
13	113.7	3.35	.312	10.7
23	113.7	3.10	.313	9.9
30	114.6	3.65	.302	11.8
12	115.7	3 33	.293	11.4
11	116.7	3.27	.294	11.1
4	117.6	2.95	.277	10.7
8	118.8	3.37	.301	11.2
3	120.9	2.82	.283	10.0
7	121.2	3.20	.288	11.1
35	121.9	3.70	.291	12.7
24	122.1	2.85	.296	9.6

TABLE 4.—*Data in Table 1 rearranged to show the relation between the weights of the samples and their composition—Concluded.*

Sample No.	Weight of six-inch sample	Humus	Nitrogen	Ratio of humus to nitrogen
	Grams	*Per cent*	*Per cent*	
26	122.6	2.90	.270	10.7
33	124.1	3.40	.306	11.1
32	124.3	3.20	.285	11.2
20	124.9	2.95	.279	10.6
22	125.1	3.17	.291	10.9
17	125.3	2.65	.317	8.4
25	125.7	2.90	.278	10.4
5	126.7	2.97	.268	11.1
18	127.0	2.67	.278	9.6
16	127.5	2.85	.278	10.3
34	127.7	3.35	.279	12.0
10	128.2	3.47	.306	11.3
29	129.7	3.40	.291	11.3
19	131.8	2.95	.303	9.7
15	132.3	3.05	.306	10.0
31	132.4	3.45	.298	11.6
9	132.7	2.92	.250	11.7
2	132.9	2.90	.276	10.5
6	133.0	3.12	.287	10.9
1	134.1	3.00	.275	10.8
Average of all	124.2	3.14	.290	10.8
Lowest five	111.3	3.29	.300	11.0
Next five	115.7	3.26	.296	11.0
Next five	121.0	3.19	.292	10.9
Next five	124.2	3.12	.286	10.9
Next five	126.4	2.81	.284	9.9
Next five	129.9	3.24	.297	10.9
Highest five	133.0	3.08	.277	11.1
Lowest ten	113.5	3.27	.298	11.0
Intermediate fifteen	123.9	3.04	.287	10.6
Highest ten	131.4	3.16	.287	11.0
Lowest twenty	118.0	3.21	.293	11.0
Highest twenty	128.4	3.06	.286	10.7

THAYER COUNTY.—Two series of samples similar to the above were taken in August, 1907, from adjacent prairie fields near Bruning, Thayer county. The first had been mown every year for hay so far as its history is known, whereas the other had been used only as a pasture. The data are given in Tables 5 and 7. Summaries are given in Tables 6 and 8 to show the effect of increasing the number of individual samples used in making a composite for analysis, and also to show the relation of the composition to the weight of the samples. In the case of only a few samples were humus determinations made.

In the first prairie the nitrogen varies from 0.227 to 0.268 per cent and in the second from 0.205 to 0.292 per cent, differences of 18 and 43 per cent respectively. By using composites of five individuals each, differences of 10 and 30 per cent respectively would have been obtained, and using composites of 10 individuals the differences would have fallen to 4 and 25 per cent respectively. Even with composites of 20 the differences, while less than 2 per cent in the first field, would have been 10 per cent in the second.

The decrease in nitrogen content with the increase of the weight of the cores is more marked with the samples from these prairies than with those from the one near Lincoln.

In the case of the second field there is a markedly higher content of nitrogen on the one side than on the other, altho so far as the history of the field is known the whole of it has been treated alike. This difference is more apt to be due to a difference in the texture of the soil in the two parts than to any difference in the history.

TABLE 5.—*Composition of individual samples from first prairie in Thayer county.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1	....	....	.267	118.8	....
2	30 feet	....	.243	132.3	....
3	30 feet	....	.247	124.7	....
4	30 feet	....	.257	129.9	....
5	30 feet	3.68	.252	120.7	14.6
6	30 feet	....	.249	124.8	....
7	2 inches	....	.254	124.8	....
8	2 inches	....	.255	129.8	....
9	2 inches	....	.257	112.4	....
10	2 inches	3.29	.265	112.4	12.5
11	30 feet	....	.247	133.1	....
12	30 feet	....	.228	123.5	....
13	30 feet	....	.255	110.4	....
14	30 feet	....	.228	127.6	....
15	30 feet	2.62	.230	126.6	11.4
16	30 feet	....	.243	123.1	....
17	2 inches	....	.254	109.0	....
18	2 inches	....	.242	120.3	....
19	2 inches	....	.254	111.6	....
20	2 inches	3.86	.261	109.0	14.8
21	30 feet	....	.213	136.3	....
22	30 feet	....	.260	115.2	....
23	30 feet	....	.228	135.8	....
24	30 feet	....	.227	135.2	....
25	30 feet	3.00	.233	122.9	12.9
26	30 feet	....	.255	125.5	....
27	2 inches	....	.252	111.3	....
28	2 inches	....	.258	117.4	....
29	2 inches	....	.254	122.5	....
30	2 inches	2.95	.260	116.3	11.3
31	30 feet	....	.257	123.3	....
32	30 feet	....	.244	131.4	....
33	30 feet	....	.268	121.9	....
	Average	....	.248	122.4	....

TABLE 6.—*Summary of data in preceding table.*

	Weight of samples	Nitrogen
	Grams	*Per cent*
Average of all	122.4	0.248
First five, 30 feet apart	125.3	0.253
Second five, 2 inches apart	120.8	0.256
Third five, 30 feet apart	124.2	0.238
Fourth five, 2 inches apart	114.6	0.251
Fifth five, 30 feet apart	129.1	0.232
Sixth five, 2 inches apart	118.6	0.256
Last three, 30 feet apart	125.5	0.256
First ten	123.0	0.254
Second ten	119.4	0.244
Last thirteen	124.2	0.247
Lightest five	110.2	0.255
Next five	114.7	0.260
Next five	120.8	0.257
Next eight	124.1	0.248
Next five	129.1	0.243
Heaviest five	134.5	0.232
Lightest ten	112.4	0.257
Intermediate thirteen	129.8	0.250
Heaviest ten	131.8	0.238

TABLE 7.—*Composition of individual samples from second prairie in Thayer county.*

Sample No.	Distance from preceding sample	Humus	Nitrogen	Weight of 6-inch sample	Ratio of humus to nitrogen
		Per cent	*Per cent*	*Grams*	
1		....	.238	147.	....
2	30 feet	....	.224	138.2	....
3	30 feet	....	.211	146.9	....
4	2 inches	....	.217	136.5	....
5	2 inches	....	.221	137.8	....
6	2 inches	....	.213	153.2	....
7	2 inches	2.30	.205	155.0	11.2
8	30 feet	....	.211	147.9	...
9	30 feet	....	.221	149.6	....
10	30 feet	....	.216	150.0	....
11	30 feet	....	.235	147.5	....
12	30 feet	2.70	.233	138.2	11.1
13	30 feet	....	.250	138.0	....
14	2 inches	....	.250	131.9	....
15	2 inches	....	.264	136.8	....
16	2 inches	....	.264	129.8	..
17	2 inches	3.15	.265	140.8	11.9
18	30 feet	....	.234	148.2	....
19	30 feet	....	.235	139.2	....
20	30 feet	....	.268	142.8	....
21	30 feet	....	.255	140.8	....
22	30 feet	3.00	.257	144.9	11.7
23	30 feet	....	.271	139.8	....
24	2 inches	....	.282	128.6	....
25	2 inches	...	.272	135.1	....
26	2 inches	....	.272	132.7	....
27	2 inches	3.48	.292	133.8	11.9
28	30 feet	....	.278	138.5	....
29	30 feet	...	.262	136.3	....
30	30 feet	....	.264	130.2	...
31	30 feet	....	.282	137.4	....
32	30 feet	3.20	.272	137.9	11.8
	Average	....	.248	140.4	....

TABLE 8.—*Summary of data in preceding table.*

	Weight of 6-inch sample	Nitrogen
	Grams	*Per cent*
Average of all	140.4	0.248
First two, 30 feet apart	143.0	0.231
Next five, 2 inches apart	145.9	0.213
Next five, 30 feet apart	146.6	0.223
Next five, 2 inches apart	135.5	0.259
Next five, 30 feet apart	143.2	0.250
Next five, 2 inches apart	134.0	0.278
Next five, 30 feet apart	136.1	0.272
First twelve	145.7	0.220
Next ten	139.3	0.254
Last ten	135.0	0.275
Lightest five	130.6	0.266
Next five	135.7	0.261
Next five	137.9	0.252
Next seven	140.0	0 257
Next five	147.0	0.230
Heaviest five	151.2	0.218
Lightest ten	133.1	0.263
Intermediate twelve	139.1	0.254
Heaviest ten	149.1	0.224

SAMPLES FROM PRAIRIES ON THE HIGH PLAINS

CHASE COUNTY.—In Table 9 are given the data on 10 individual samples from a prairie two miles east of Imperial, collected in September, 1907. The variation between extremes amounts to over 30 per cent of the lowest; but almost any combination of five—the heaviest, the lightest, the first or the last—gives entirely satisfactory results, both for humus and for nitrogen. While the lightest samples are slightly higher in humus and in nitrogen the differences are small.

TABLE 9.—*Composition of individual samples from virgin prairie near Imperial.*

Sample No.	Distance from preceding sample	Humus	Humus ash	Nitrogen	Weight of 6-inch sample
		Per cent	*Per cent*	*Per cent*	*Grams*
1	.....	0.81	.28	.136	161.5
2	30 feet	0.76	.34	.110	170.8
3	30 feet	1.05	.43	.146	157.3
4	30 feet	0.70	.34	.131	168.8
5	30 feet	0.87	.46	.136	157.3
6	30 feet	1.06	.35	.155	148.8
7	30 feet	0.72	.33	.117	141.2
8	30 feet	0.93	.39	.131	156 3
9	30 feet	0.72	.33	.130	146.8
10	30 feet	0.99	.32	.143	152.3
	Average	0.86	.36	.134	156.0
Average of heaviest five		0.84	...	.132	163.1
Average of lightest five		0.88	...	.135	149.1
Average of first five		0.84	...	.132	163.1
Average of last five		0.88	...	.135	149.1

PERKINS COUNTY.—In November, 1907, about 90 individual samples were collected on various parts of the H O Ranch, north of Madrid. All but the extreme northern part of the ranch lies in Township 11 and Range 37. The samples were taken in seven series, the number in a series varying from five to twenty. The samples of each series were taken in a straight line at intervals of 30, 60, 100, or 200 feet. On the south part of the ranch, consisting of gently rolling "hard land," sets 1, 2, 3, and 7 were taken. In the case of all of these the prairie was covered with buffalo grass and all were taken within one mile of one another on what appeared to be uniform soil.

Nos. 1061 to 1065 were taken on the north half of Section 29 at intervals of 30 feet.

Nos. 1066 to 1080 were taken on the west half of Section 28 at intervals of 60 feet.

Nos. 1081 to 1100 were taken on the west half of Section 28 and on the southwest corner of Section 21 at intervals of 100 feet.

Nos. 1128 to 1147 were taken on the west half of Section 30 at intervals of 100 feet.

On the north part of the ranch, lying four or five miles from the south part, series 4, 5, and 6 were taken. This part of the

ranch is much more sandy than the south part and is commonly known as "sandy land," but not as "sand hill land."

Nos. 1101 to 1110 were taken on the southwest quarter of Section 5 at intervals of 75 feet. Buffalo grass was present where the samples of the first part of the series were taken.

Nos. 1111 to 1115 were taken on the northwest quarter of Section 5 at intervals of 100 feet. No buffalo grass was observed in this prairie.

Nos. 1117 to 1126 were taken at intervals of 200 feet from a field just north of Section 5 which had been plowed about 1890, cultivated for a few years, and later abandoned. It had since become covered with a thin stand of grasses.

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county.*

Soil No.	Nitrogen	Humus	Humus ash
	FIRST SERIES		
	Per cent	*Per cent*	*Per cent*
1061	.120	.67	.36
1062	.130	.74	.38
1063	.121	.76	.45
1064	.100	.62	.36
1065	.124	.63	.45
Average	.119	.68	...
	SECOND SERIES		
1066	.096	.68	.40
1067	.098	.61	.35
1068	.124	.61	.44
1069	.099	.70	.36
1070	.125	.79	.38
1071	.171	1.30	.50
1072	.179	1.34	.56
1073	.228	1.57	.41
1074	.201	1.26	.51
1075	.209	1.08	.39
1076	.171	1.08	.50
1077	.138	.99	.48
1078	.148	1.00	.57
1079	.135	.77	.43
1080	.127	.75	.38
Average	.150	.97	...
Average for slope to east	.140	.95	...
Depression	.202	1.25	...
Slope to west	.137	.88	...

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county—Continued.*

THIRD SERIES

Soil No.	Nitrogen	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*
1081	.158	1.12	.56
1082	.124	.67	.49
1083	.103	.64	.47
1084	.124	.95	.33
1085	.199	1.81	.63
1086	.164	1.48	.54
1087	.149	1.36	.74
1088	.160	1.34	.58
1089	.172	1.35	.58
1090	.110	.85	.52
1091	.114	.96	.32
1092	.134	.78	.39
1093	.123	.76	.54
1094	.124	.85	.34
1095	.118	1.14	...
1096	.142	1.26	.76
1097	.151	1.03	.52
1098	.103	.70	.42
1099	.094	.73	.37
1100	.094	.73	.56
Average	.133	1.02	...

FOURTH SERIES

1101	.131	1.02	.38
1102	.141	.98	.39
1103	.179	1.59	.56
1104	.157	1.42	.46
1105	.167	1.28	.41
1106	.091	.95	.41
1107	.082	.80	...
1108	.087	.86	.29
1109	.097	.64	.42
1110	.101	.70	.36
Average	.122	.94	.

FIFTH SERIES

1111	.079	.55	.42
1112	.092	...	...
1113	.039	...	...
1114	.052	.48	.46
1115	.071	...	...
Average	.067	...	. .

TABLE 10.—*Composition of individual samples from prairies near Madrid, Perkins county—Concluded.*

SIXTH SERIES

Soil No.	Nitrogen	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*
1117	.082	.70	...
1118	.112	.95	.58
1119	.109	.78	.48
1120	.106	.98	.48
1121	.097	.75	...
1122	.099	.75	.55
1123	.102	.75	...
1124	.104	.75	.55
1125	.093	.60	.36
1126	.089	.58	.42
Average	.099	.76	...

SEVENTH SERIES

1128	.144	1.09	.60
1129	.157	1.10	...
1130	.163	.92	.47
1131	.137	1.07	.43
1132	.151	1.16	.46
1133	.151	1.01	.52
1134	.158	1.01	...
1135	.134	.93	.50
1136	.153	1.33	.54
1137	.134	1.00	.65
1138	.131	.86	.78
1139	.118	.81	.46
1140	.106	.81	.71
1141	.147	1.15	.80
1142	.106	.80	.62
1143	.112	1.10	.58
1144	.147	1.18	.55
1145	.118	.85	.54
1146	.118	.87	.57
1147	.112	.67	.44
Average	.135	.99	...

TABLE 11.—*Summary of data in Table 10.*

	Nitrogen	Humus
	Per cent	*Per cent*
First series—5	.119	.68
Second series—15	.150	.97
Third series—20	.133	1.02
Fourth series—10	.122	.94
Fifth series—5	.067	...
Sixth series—10	.099	.76
Seventh series—20	.135	.99
SERIES ARRANGED IN ORDER OF NITROGEN CONTENT.		
Second series	.150	.97
Seventh series	.135	.99
Third series	.133	1.02
Fourth series	.122	.94
First series	.119	.68
Sixth series	.099	.76
Fifth series	.067	...

In the second series the first seven samples were from the west side of a depression and the last four from the east side. The other four were from the bottom of the depression. It will be seen that the nitrogen and humus are distinctly higher in the samples from the bottom of the depression than in those from either slope. The samples from the hard land show a much higher nitrogen content than those from the sandy land. Likewise the buffalo grass tracts show a higher nitrogen content than the sand grass tracts. Both the presence of the buffalo grass and the high nitrogen content are to be regarded as due to the heavier texture of the soil in the case of the hard land.

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ON THE SAMPLING OF CULTIVATED SOILS

By F. J. Alway and E. K. Files

The methods of analysis used were similar to those described on page 36 of this Report. In taking samples to a depth of six inches the sampler described above was used.

In August, 1907, 12 individual samples were taken in a field that had been under cultivation for 40 years and had been sown to alfalfa in the preceding spring. The field lies near some large stock feeding barns and had been heavily manured for many years, it having been used to produce forage. The history of the field and the conditions under which the alfalfa started have been described for Field I on page 9 of the Twenty-Third Annual Report of the Nebraska Experiment Station. The data on these samples are given in Table 1.

Table 1.—*Composition of individual soil samples taken from a field of young alfalfa.*

Sample No.	Condition of alfalfa	Humus	Nitrogen
		Per cent	*Per cent*
1	Better than the average	2.90	.227
2	Less vigorous than at 1	2.55	.207
3	Less vigorous than at 1	2.65	.213
4	Like that at 1	2.45	.213
5	Very vigorous	2.70	.238
6	Very yellow and stunted	3.00	.241
7	Very yellow and stunted	2.85	.238
8	Better than at 7	2.60	.221
9	Better than at 8	2.60	.220
10	Very vigorous	2.30	.220
11	Very vigorous	2.45	.206
12	Very vigorous	2.55	.210
Average		2 62	.221
Average of first five		2.65	.220
Average of last five		2.50	.215

Another method of sampling was tried in the same field on December 15, 1908, the samples being taken from the highest

portion of the field. At this time the alfalfa had made two seasons' growth. The method of sampling was as follows: Two stakes were placed 4 rods apart and with these as centers two circles, each 10 feet in diameter, were described. In each circle an equilateral triangle was inscribed and from the six points of contact of the triangles with the circles samples were taken by means of the six-inch sampler, previously described. Then both triangles were rotated thru a distance of one foot and another set of composite samples similarly taken, this being repeated until 10 composites in all had been taken. Thus from each of the areas, four rods apart, 30 samples had been taken in a circle at intervals of one foot.

On the following day a similar set of 10 composite samples was taken from a field which had been in brome grass for about 15 years and previous to that time had been in cultivation about 20 years. The data for the fields are given in Table 2.

TABLE 2.—*Nitrogen content and weight of different samples from the same field.*

Sample No.	Nitrogen		Average weight of each sample dried at 110° C.	
	Alfalfa field	Brome grass field	Alfalfa field	Brome grass field
	Per cent	*Per cent*	*Grams*	*Grams*
1	.202	.231	119.1	94.8
2	.207	.241	106.5	99.5
3	.202	.226	116.3	98.1
4	.205	.226	109.5	93.6
5	.216	.231	121.0	87.0
6	.205	.235	106.3	87.7
7	.206	.232	115.3	89.6
8	.202	.229	108.3	89.0
9	.200	.229	115.7	92.5
10	.199	.235	112.6	95.1
Average	.204	.231	113.1	92.7
Highest	.216	.241	119.1	99.5
Lowest	.199	.226	106.3	87.0

It will be seen that the extremes of nitrogen were .216 and .199 in the alfalfa field and .241 and .226 in the brome grass field. Nine of the samples from the alfalfa field gave concordant results, but one gave .009 per cent more nitrogen than the next highest. In the brome grass field there was a greater variation among the ten composites and in some cases no improvement in accuracy would have been effected by using twelve individuals, instead of six, as a composite. In general, however, the accuracy would have been increased by every increase in the number of samples used in making the composite.

There was a similar variation in the average weight of the cores. The samples from the brome grass field were in all cases decidedly lighter than those from the alfalfa field, the lightest set from the alfalfa field being decidedly heavier than the heaviest set from the brome grass field. In order to have gotten the same weight of soil from the brome grass field it would have been necessary to take the samples in this to a depth of seven and one-third inches against six inches in the alfalfa field. The effect on the nitrogen content of the samples that would have been caused by this is shown in Table 3. There would have been practically no effect. Hence the difference in the weights of the samples was without appreciable influence upon the results.

In order to determine the effect of sampling to different depths, due to the soil being loose in some cases and compact in others, two sets of 12 samples each were taken to a depth of one foot from near the above described circles in the same two fields and these were divided into inch sections. The resulting sections were combined to form composite samples for each inch. The data on these are given in Table 3. In the second part of the table there are shown the percentages which would have been obtained had the samples been taken to 2, 3, 4, etc., inches. In the alfalfa field every increase in depth by one inch would have lowered the nitrogen content more or less, but in the brome grass field practically no difference would have resulted from taking a

sample to a depth of 4, 5, 7, or 8 inches instead of 6. Below the eighth inch there was a steady decline in nitrogen. Even in the alfalfa field the effect of having taken the sample to a depth of five or of eight inches instead of six would have been slight. Hence, we are safe in concluding that no special precautions would need to be exercised in sampling these two fields so as to get samples of the same weight, but that the precaution that should be taken is that of increasing the number of individual samples used in making the composites.

TABLE 3.—*Nitrogen content of different inch sections of the surface foot of soils in two long cultivated fields.*

Depth of section	Alfalfa field	Brome grass field
	Per cent	*Per cent*
First inch	.213	.222
Second inch	.212	.230
Third inch	.198	.231
Fourth inch	.192	.223
Fifth inch	.194	.226
Sixth inch	.192	.224
Seventh inch	.190	.222
Eighth inch	.185	.222
Ninth inch	.180	.209
Tenth inch	.171	.196
Eleventh inch	.159	.196
Twelfth inch	.151	.177
Average	.186	.216
First inch	.213	.222
Average to two inches	.212	.226
Average to three inches	.208	.228
Average to four inches	.204	.226
Average to five inches	.202	.226
Average to six inches	.200	.226
Average to seven inches	.199	.225
Average to eight inches	.197	.225
Average to nine inches	.195	.223
Average to ten inches	.193	.221
Average to eleven inches	.190	.218
Average to twelve inches	.186	.216

SOME NOTES ON ALFALFA AND CLOVER RESIDUES AS SOURCES OF SOIL NITROGEN

By F. J. Alway and E. S. Bishop

It has already been pointed out in publications of this Station[1] that the problem of maintaining the fertility of the loess soils of eastern Nebraska is, in so far as the chemical composition is concerned, essentially that of maintaining the supply of total organic matter, which includes both humus and nitrogen. The problem with the loess soils of western Nebraska also, in so far as the chemical composition is concerned, is the same. The only two sources of nitrogen that are at present to be recommended to Nebraska farmers are barnyard manure and leguminous crops. Of course all crop residues, such as straw, cornstalks, etc., should be returned to the soil instead of being burned, as is, at present, too commonly the case. Whether the hay should be fed and the part of the nitrogen in the form of manure returned to the fields, or whether the entire leguminous crop should, from time to time, be plowed under, is a disputed question. It will be much harder to persuade a farmer to use a rotation including a leguminous crop to be plowed under than one where he gathers the hay and plows under only the plant residues, including fallen leaves, stubble, etc. In both cases the roots from the legumes are left in the soil. It is claimed by some that where clover is grown and the aerial portion of the plants removed, the soil does not become any richer in nitrogen. Thus Hopkins[2] states, "When grown on soil of fair productive capacity, the roots and stubble of the clover plant contain no more nitrogen than the soil has furnished to the plant." Whether this is the case in Nebraska we do not have data from which to decide. For practical purposes it really is not a very important question. The amount of residues that the farmer involuntarily leaves on a field is very

large. These residues steadily become incorporated in the surface soil even tho no cultivation takes place. The manner of this incorporation is discussed elsewhere in this Report. Further, there will usually be at least a very considerable portion of the hay fed on the same farm where it is produced, the manure from this being returned to the fields and thus still further increasing the nitrogen supply resulting from the growth of legumes on the farm. Provided only that the farmer produce a large enough acreage of legumes and make the best use of all the barnyard manure produced on his farm, it is probable that he need give himself no concern regarding the theoretical question alluded to above. At all times he should remember that the greatest losses of nitrogen are due to erosion by wind and water and that it is simpler to check this erosion than it is to replace the nitrogen lost thereby.

In the absence of any extended study of this subject in Nebraska, all local data bearing upon it become of interest and for this reason the following notes are published at this time.

At the Experiment Station Farm, Lincoln.—Early in the spring of 1910 a field on the Experiment Station Farm was sown to red clover, no nurse crop being used. A very thick and uniform stand was secured and the plants made a most luxuriant growth. The field was mown about September 1 and the hay removed. August had been a remarkably wet month, 14.41 inches having fallen at the Experiment Station, and of this 8.60 inches fell during one night, that of August 29 to 30. The aftergrowth was allowed to stand without pasturing and plowed under during the latter part of October. On the 21st of that month, when the plowing had been nearly finished, we collected the roots and the above-ground portions of the clover plants from three places about 50 yards apart. These seemed to be representative of the field, and the differences in the stand were not noticed until the count was made. At each of these three places a square foot was measured off accurately and the soil removed

to a depth of one foot and placed on a large sheet of paper. The roots and above-ground portions of the plants were carefully removed, counted, and washed free of soil. After the roots had been separated from the aerial portions, the two parts were dried separately at 110° C., weighed, and analyzed. On the one square foot there were 23 plants and on the other two 53 and 59, respectively. The roots from the 135 plants weighed, after drying, 58.7 grams and had a nitrogen content of 2.17 per cent. The aerial portions, after drying, weighed 124.2 grams and had a nitrogen content of 3.42 per cent. Calculated on this basis the amount of roots and aerial portions per acre would be 1,882 pounds and 3,976 pounds, respectively. The roots would have contained 41 pounds of nitrogen per acre and the tops 136 pounds, making 177 pounds in all. The weight of the air-dried aerial portions was far greater than could have been gathered in the form of hay had the field been mown in the latter part of October, for the reason that a great many stems and leaves were lying dead on the surface and there would have been a comparatively dense mat of stubble left by the mower.

On November 12 of the same year the roots alone were gathered from three typical cubic foot sections in a young alfalfa field just east of the factory of the Nebraska Silo Co. The plants had very little top left, so little that it was not representative of the conditions in a hay field, and for this reason the tops were rejected, the roots only being used for analysis. The field had been heavily manured for many years and had been sown to alfalfa in the autumn of 1909, a large amount of seed being used and a very thick stand of plants resulting. On the three areas where the samples were taken this was found to vary from 42 to 52 plants per square foot. The data are given in Table 1. Calculated from the data in the table the weight of the roots was 3,650 pounds and the nitrogen content of the roots to a depth of one foot would amount to 73 pounds per acre, nearly twice as much as that contained in the roots in the clover field described above.

TABLE 1.—*Alfalfa plants on one square foot.*

Sample No.	Number of plants per square foot	Weight dried at 110° C.	Nitrogen	Weight of nitrogen
		Grams	*Per cent*	*Grams*
1.....	42	39.9	2.12	0.86
2.....	52	37.8	1.97	0.74
3.....	42	34.9	1.92	0.67
Average	45	37.5	2.00	0.76

In order to secure some data as to the amount of nitrogen contained in the residues left on an alfalfa field, samples were collected from three typical areas of one square yard each in different parts of the field described as "Field I" on page 10 of the Twenty-third Annual Report of the Nebraska Experiment Station. This field had been in alfalfa for five years, not being pastured at all. The last cutting of hay in 1910 had been made very late in October and very little after-growth had appeared between the time of cutting and the time of sampling, November 12. The living plants were cut off even with the surface and all dead stems, leaves, etc., lying on the ground were carefully gathered. The whole of this organic matter, consisting of leaves, stems, and partly decayed residues, was dried, weighed, and analyzed. The data are given in Table 2. This may be regarded as strictly representative of the ordinary alfalfa fields in which there is a good stand of plants. Calculated from the average weight of the three samples the weight of alfalfa residues per acre would amount to 5,478 pounds with a nitrogen content of 126 pounds.

TABLE 2.—*Alfalfa residues on one square yard.*

Sample No.	Weight of residues dried at 110° C.	Nitrogen	Weight of nitrogen
	Grams	*Per cent*	*Grams*
1.....	406	2.45	9.96
2.....	435	2.62	11.40
3.....	768	1.84	14.13
Average ...	536	2.30	11.83

At the Farm of Hon. George Coupland near Elgin.—In the latter part of September, 1910, the roots were collected from the surface foot of a field of Mammoth red clover which had been sown with winter wheat the year before. On the same day the roots of alfalfa plants were similarly collected from a field sown in 1908.

Table 3.—*Alfalfa and clover roots from one cubic foot.*

	Weight of roots dried at 110° C.	Nitrogen	Nitrogen per acre
	Grams	*Per cent*	*Pounds*
Clover field	19.4	1.69	32
Alfalfa field.....	40.8	1.91	76

At the time the above samples were collected two pits had been dug to permit of the taking of samples for bacteriological studies,[3] and, from the walls of these, samples were taken for nitrogen determinations. The pits were four feet long, two and one-half feet wide, and twelve feet deep, with vertical walls. The one was within a cornfield which had been in continuous cultivation for 28 years without the application of any manure or fertilizers and on which no leguminous crops had been grown. The other pit was in a field differing from that just mentioned in that it had during the preceding 8 years been in alfalfa, all the crops being removed as hay and no fertilizers applied. The latter pit was about 60 feet within the edge of the alfalfa field and had accordingly, been surrounded on all sides by a good stand of alfalfa plants. During the preceding winter the plants in many parts of the field had died out. Several counts were made where a fair stand of plants still remained. At these places the stand was probably as full as it had been before any winterkilling occurred. The different counts gave an average of 8 plants to the square foot.

All the alfalfa roots exposed in the pit had penetrated beyond the twelfth foot, at which depth many of them were 2 mm. in

diameter. On account of the very dry condition of the soil at the time, it was not found feasible to remove the roots intact. Of some twenty roots which we attempted to remove, only eleven were secured intact to a depth of three feet and only one to a depth of four, this one being secured intact to a depth of a little over ten feet. It is shown in the accompanying photograph. The eleven 3-foot roots were cut up into foot sections, dried and analyzed. The 10-foot root was treated similarly. The data are given in Table 4. The alfalfa roots in the subsoil were surrounded by a black, humus-like layer.

The first ten feet of root of a typical eight-year-old alfalfa plant from near Elgin, Nebraska.

TABLE 4.—*Weight and nitrogen content of foot sections of roots of alfalfa plants eight years old.*

Depth	Ten-foot root from one plant		Three-foot roots from eleven plants	
	Dry weight	Nitrogen	Dry weight	Nitrogen
Feet	*Grams*	*Per cent*	*Grams*	*Per cent*
1	7.06	1.89	73.20	2.07
2	2.57	2.10	21.88	1.84
3	1.29	1.87	11.58	1.82
4	.85	....	.....	....
5	.43	....	.....	....
6	.26	....	.....	....
7	.27	....	.....	....
8	.22	....	.....	....
9	.17	....	.....	....
10	.18	....	.....	....

From the data in the above table an estimate has been made of the amount of nitrogen in the form of alfalfa roots contained in the various acre-foot sections, it being assumed that the roots analyzed were average specimens, that there had been a stand of eight plants to the square foot, and that the weight of an acre-foot of soil is 3,500,000 pounds.

TABLE 5.—*Organic matter and nitrogen contained in roots of alfalfa plants in a field which had been in alfalfa eight years.*

Depth	Weight of organic matter			Nitrogen		
	Per plant	Per cubic foot	Per acre-foot	In dry roots	Per acre foot	In soil layer in the form of alfalfa roots
Feet	*Grams*	*Grams*	*Pounds*	*Per cent*	*Pounds*	*Per cent*
1	6.60	52.8	5,069	2.07	104.9	0.00300
2	2 00	16.0	1,536	1.84	28.3	0.00080
3	1.05	8.4	806	1.82	14.7	0.00040
4	.85	6.8	653	1.51	9.9	0.00030
5	.43	3.4	330	1.18	3.9	0.00010
6	.26	2.1	200	.99	2.0	0.00006
7	27	2.2	207	1.12	2.3	0.00007
8	22	1.8	169	.94	1.6	0.00004
9	.17	1.4	135	1.12	1.5	0.00004
10	.18	1.4	135	1.00	1.5	0.00004

From both pits the samples of soil, except for the first foot, were secured by first removing a layer six inches in thickness from the face of the wall and then taking half a cubic foot of soil from behind this. This large sample was thoroly mixed and a five-pound sample taken for analysis. Alfalfa roots were removed before grinding, for analysis. For the samples of the surface foot of soil from each of the two fields twelve borings from various parts of the fields were combined as composites. The undecayed alfalfa roots were not included in the sample of soil from the surface foot of the alfalfa field. The data are given in Table 6.

TABLE 6.—*Nitrogen in the soil of the two fields at different levels.*

Depth	Cornfield		Alfalfa field	
	Per cent	Pounds per acre-foot	Per cent	Pounds per acre-foot
Feet				
1 ...	.157	5,495	.166	5,810
2....	.107	3,745	.075	2,625
3....	.074	2,590	.055	1,925
4....	.050	1,050	.040	1,400
5....	.024	940	.054	1,890
6....	.021	735	.036	1,260
7....	.027	945	.025	875
8....	.017	595	.022	770
9....	.022	770	.020	700
10....	.019	665	.016	560
11....	.019	665	.021	735
12....	.022	770	.022	770

No marked difference is to be seen between the amounts of nitrogen in the soils of the two fields as represented by the samples analyzed. The relative nitrogen content at any level appears to be determined by the texture of the soil at that level rather than by the cultural history of the field. While the percentages of nitrogen in the subsoils of the two fields are low, the total quantity is still large and in comparison with this the nitrogen contained in the alfalfa roots is insignificant.

TABLE 7.—*Weight of nitrogen per acre-foot in soil and in alfalfa roots at different levels.*

Depth	Cornfield	Alfalfa field	
	In the soil	In the soil	In the alfalfa roots
Feet	*Pounds*	*Pounds*	*Pounds*
1	5,495	5,810	105
2	3,745	2,625	28
3	2,590	1,925	15
4	1,050	1,400	10
5	940	1,890	4
6	735	1,260	2
7	945	875	2
8	595	770	2
9	770	700	1
10	665	560	1

On the alfalfa roots as exposed on the pit walls, but few nodules were found within the first eight inches, but at a greater depth they were numerous, many large clusters being found in the second and third feet and one very large cluster at a depth of four feet. All of these deeply located clusters had apparently formed in old, vertical fissures formed by the shrinkage of the soil.

The absence of nodules on the alfalfa roots near the surface is no evidence of the lack of inoculation when the observations are made during a protracted drouth. In the latter part of August, 1911, we made many attempts to find nodules on alfalfa roots in the fields near the Experiment Station Farm, fields which we had inspected at frequent intervals for several years without previously failing to find nodules during the growing season. In all cases, however, the examinations made in August, 1911, were to a depth of only 10 inches. The surface soil was very dry and had been so during much of the summer on account of a protracted drouth. However, nodules were always to be found on some alfalfa plants growing on exposed subsoil where the plants were small and far apart and the soil, accordingly, moist.

At the H O Ranch, Perkins County.—On November 12, 1907, an excavation to a depth of 7 feet was made in a field of dry land alfalfa sown in 1905. All the living plants had roots extending to a depth of 4½ to 5 feet and about one-third of them extended below the bottom of the excavation. The largest roots found at that depth were 2 mm. in diameter. Counts were made of the plants per square yard in three typical places in each of three fields sown two years before. The averages were 16, 14, and 10 per square yard. A large number of plants were dug up and on about three-fourths of these nodules were found. The ground was very dry and it is not improbable that the nodules on the other plants had been torn off on removing the adherent soil.

REFERENCES

1. Alway: Changes in the composition of the loess soils of Nebraska caused by cultivation, Bulletin 111, Nebraska Experiment Station (1909).
2. Hopkins: Soil fertility, p. xxi (1910).
3. Waite and Squires: A comparative study of the bacterial content of soils from fields of corn and alfalfa, Twenty-fourth Annual Report, Nebraska Experiment Station, page 150 (1911).

A COOPERATIVE INVESTIGATION ON THE LOSSES OF NITROGEN, ORGANIC MATTER, AND HUMUS FROM SOME NEBRASKA SOILS

By F. J. Alway and E. S. Bishop

This Experiment Station very frequently receives samples of soil from farmers and other land owners in the state, with the request that these be analyzed and the analyses reported to the sender. There is no provision at this Experiment Station for the expenses connected with such work, the funds used for the maintenance of the experimental work of the Department of Agricultural Chemistry being derived almost entirely from appropriations made by the Federal Government for specific investigations. The actual cost of a complete soil analysis is about $25, the exact amount depending upon the skill of the analyst, upon the rate of remuneration he receives, and upon various other varying factors, and the results are likely to be of *no value at all* unless the samples be taken properly. In practically no cases are the samples so taken. Usually the sender has only scraped off from the surface a few ounces of soil, but occasionally he has also taken from below the furrow slice, at a depth of 6 to 10 inches, a very small sample, this usually being secured by digging a shallow hole in a single place. When he is informed that the analysis of such samples would be useless and is sent specific directions for sampling, seldom is he willing to go to the trouble required to properly take the sample, even when the offer of an analysis without charge is made.

Occasionally the investigation under way is of such a nature that the analysis of properly taken samples sent in by farmers would fit into the investigation and, accordingly, it would be economical for the Station to have the farmers take them on their own farms, provided they would take them exactly accord-

ing to directions. As an illustration we might cite the case of an investigation of soils in a well-settled community in western Nebraska. About 10 sets of samples, each consisting of one of surface soil and one of subsoil, were desired in connection with an investigation being carried on, and it was necessary either to send an assistant of the Experiment Station to take the samples, or to ask some of the farmers in the vicinity to take them and send them in. As several letters had been received asking for information regarding the advisability of the use of commercial fertilizers on these soils, and as a number of samples taken as above described had been sent in for analysis, it was thought that the farmers might be enough interested to take the samples in order that they might have the analyses without incurring any expense. Accordingly, an offer was made to analyze, without charge, ten such sets of samples, the Experiment Station sending sample sacks and paying the transportation charges. Not a single set of samples has yet been received.

In 1909 an offer to make free soil analyses for graduates and students of the School of Agriculture was rendered possible by the need of a large number of samples of surface soil from various parts of the State. Accordingly, in the issue of "Agriculture" for September, 1909, the following offer was made:

"Analyses showing the nitrogen, organic matter, and humus will be made without charge for all graduates and students of the School of Agriculture who take the samples according to directions and who deliver them to the Experiment Station not later than January 30, 1910. All those wishing to take advantage of this offer should send a postal card or letter to the chemist so that he may send them directions and soil sacks. The samples taken and prepared should not weigh more than two pounds, and as only two samples will be analyzed for any one person, the total expense to the graduate or student, in case he cannot deliver them personally to the Experiment Station, will amount to only the express charges on the four-pound package."

Requests for directions and soil sacks were received from 22

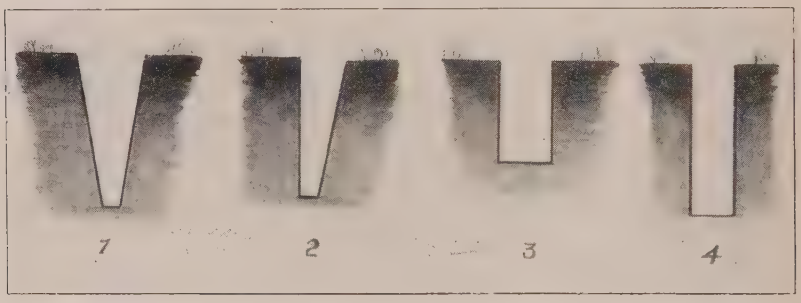
of the graduates and students but of these only 15 delivered samples. The results of the analyses are given in the table below. The names of the senders are not given, they having been informed of the series number of their samples.

The directions sent to each man are given in the following paragraphs:

DIRECTIONS FOR TAKING SAMPLES OF SURFACE SOIL.

"If the samples are not taken with full attention to directions the results obtained from the analyses will have little or no significance.

"For the sample of long cultivated soil select as level a field as you have which has not been manured and of which you know the approximate date of breaking. If all your fields have been manured or if you do not know their history it would be well to get the samples from some neighbor's field to which no manure has been applied and of which the history is known.



"The sample of virgin soil should be taken from the nearest remaining prairie whether it has been used as pasture or as hay-land. If the prairie is bottom land the cultivated field should be bottom land.

"From ten points in the cultivated field, no two being less than 20 feet apart, take ten samples six inches deep, using a spade. Place the ten samples on a large sheet of paper, such as a newspaper, and mix the soil thoroly. With this mixture fill one sack at least half full.

"In the prairie field mark ten points, at least 20 feet apart, and at these cut the grass and weeds level with the surface.

Then take the sample as described above. In this case it is extremely important that the samples be taken to a depth of just 6 inches and that the walls be vertical, because the amounts of nitrogen, humus, and organic matter all decrease rapidly from the surface downward. Thus samples from holes like 1, 2, and 3 will be richer than those from holes like 4."

The nitrogen percentages were determined and from these the total organic matter and the humus were calculated, there being in the case of the surface soil a practically constant relationship between the amount of nitrogen and the amount of the other two constituents, altho the ratios of the nitrogen to the organic matter and to the humus in the cultivated fields are different from those in the case of the virgin prairies. On none of the fields, to the knowledge of the owners, had leguminous crops been grown and on none except numbers 7, 12, and 14 had barnyard manure been applied, and on each of these only once.

In all cases, as was to be expected, there had been a decline in nitrogen, organic matter, and humus. On account of the small number of cases in which the full history of the cultivated fields was known by the senders it is not possible from the above data to indicate the relationship between the losses of nitrogen and the length of time the fields had been under cultivation.

A detailed discussion of the changes in the chemical composition of the loess soils of Nebraska which have been caused by cultivation has been given in Bulletin 111 of this Experiment Station.

Series No. of sender	County	Number of years in cultivation	Nitrogen			Total organic matter			Humus		
			Prairie	Cultivated field	Loss	Prairie	Cultivated field	Loss	Prairie	Cultivated field	Loss
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	Colfax	13	.255	.226	.029	5.35	4.25	1.10	2.45	1.98	.47
2	Buffalo	..	.238	.197	.041	4.78	3.51	1.27	2.02	1.73	.29
3	Hamilton	..	.174	.152	.022	3 50	2.70	.80	1.46	1.34	.12
4	Wheeler	..	.340	.278	.062	7.14	5.23	1.91	3.26	2.65	.61
5	Gage	..	.235	.217	.018	4.60	3.99	.61	2.68	2.43	.25
6	Sarpy	56	.252	.171	.081	4.94	3.75	1.19	2.87	1.91	.96
7	Dodge	..	.315	.247	.068	6.61	4.64	1.97	2.60	2.17	.43
8	Antelope	20	.210	.198	.012	4.41	3.72	.69	2.02	1.74	.28
9	Richardson	40	.210	.183	.027	4.11	3.37	.74	2.39	2.05	.34
10	Thayer	..	.219	.169	.050	4.29	3.10	1.19	2.50	1.89	.61
11	Polk	..	.284	.231	.053	5.56	4.25	1.31	3.24	2.58	.66
12	Burt	32	.302	.212	.090	6.34	3 98	2.36	2.90	1.86	1.04
13	Polk	..	.210	.186	.024	4.12	3.42	.70	2.39	2.08	.31
14	Dodge	35	.306	.200	.106	6.15	3.56	2.59	2.57	1.76	.81
15	York	..	.257	.198	.059	5.02	3.64	1.38	2.93	2.22	.71

ON THE DETERMINATION OF SOIL MOISTURE

By R. S. Trumbull

The following data indicate the degree of accuracy which may conveniently be attained when one has occasion to make moisture determinations at places far from any laboratory and where he is provided with no apparatus except a small balance, a set of weights, and some tin cans, such as empty baking powder or cocoa cans.

In November, 1907, a large number of samples of soil were taken for moisture determinations at the H O Ranch in Perkins county, Nebraska. All samples, as they were taken in the field, were placed in quart fruit jars, which were at once tightly covered and in the evening taken to the ranch house. The contents of each jar were thoroly mixed and samples of 100 grams weighed out in duplicate and placed in small weighed cotton sacks. These were later shipped by express to the Experiment Station and there dried at 110° C. in an electric oven thru which a rapid current of air was kept passing. Wishing some immediate information as to the moisture in different fields, samples from five fields were dried in the oven of the ranch cook-stove. The results agreed so well with those obtained at the laboratory that they are given below.

After placing the weighed samples in the cotton sacks, similar samples were weighed out into small tin cans, which were placed in the oven of the cook-stove in the evening and removed the next morning. The following evening the samples were dried for a few hours, then covered tightly and allowed to cool during the night, being weighed the following morning. This drying was continued until no further loss in weight was caused by an evening's drying. The agreement between the determinations made in the range oven and those made in the laboratory as above de

scribed is shown in Table 1, while the agreement of duplicate determinations made in the cook-stove oven are shown in Table 2.

The results obtained by using the cook-stove oven are, accordingly, entirely satisfactory for all practical purposes. The greatest source of error evidently lies in the absorption of hygroscopic moisture from the air during the cooling. If the drying be thoro and the can be at once covered with a tight-fitting cover any error from this source can be avoided.

TABLE 1.—*Moisture content as determined in the oven of a cook-stove, compared with that found by drying in a laboratory oven.*

Depth	Laboratory oven	Cook-stove oven	Difference
Feet	*Per cent*	*Per cent*	*Per cent*
FIRST FIELD.			
1	11.5	11.0	.5
2	11.1	9.9	—1.2
3	9.5	9.8	.3
4	10.0	9.9	.1
5	8.8	9.3	.5
6	9.1	9.2	.1
7	10.2	9.7	— .5
Average	10.0	9.8	— .2
SECOND FIELD.			
1	12.8	10.5	—2 3
2	9.1	9.3	.2
3	7.2	6.5	— .7
4	5.1	4.8	— .3
5	5.5	4.8	— .7
6	7.5	7.7	.2
7	11.3	11.1	— .2
Average	8.3	7.8	— .5
THIRD FIELD.			
1	9.5	10.0	.5
2	12.4	13.4	1.0
3	14.8	14.6	— .2
4	20.7	20.8	.1
5	14.4	13.5	— .9
6	10.7	10.2	— .5
7	10.1	9.0	—1.1
8	12.5	12.0	— .5
9	11.2	10.9	— .3
Average	12.9	12.7	— .2

TABLE 1.—*Moisture content as determined in the oven of a cook-stove, compared with that found by drying in a laboratory oven—Concluded.*

FOURTH FIELD.

Depth	Laboratory oven	Cook-stove oven	Difference
Feet	*Per cent*	*Per cent*	*Per cent*
1	10.6	10.2	— .4
2	14.3	14.3	.0
3	15.2	15.6	.4
4	14.7	15.5	.8
5	12.7	12.0	— .7
6	16.0	15.8	— .2
7	13.6	13.6	.0
8	12.3	13.0	.7
9	12.2	12.7	.5
Average	13.5	13.6	.1

TABLE 2.—*Concordance of duplicate moisture determinations made in cook-stove oven, using samples from a summer-fallow.*

Depth	1	2	Average	Difference
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	18.4	18.1	18.3	.3
2	22.1	22.2	22.1	.1
3	20.0	20.2	20.1	.2
4	16.8	17.5	17.1	.7
5	17.1	16.8	17.0	.3
6	16.3	16.0	16.1	.3
7	10.0	10.2	10.1	.2

THE DETERMINATION OF TOTAL MANGANESE IN SOILS

By Ross A. Gortner and Clayton O. Rost

INTRODUCTION

It is a well-known fact that the gravimetric estimation of small quantities of manganese, such as occur in rocks or soils, is highly inaccurate even when great care is used. The inaccuracy may be caused by a number of factors, including incompleteness of separation from the iron and aluminum, incomplete precipitation, and contamination of the precipitate by other substances. These errors, because of the small amounts of manganese present, cannot be depended upon to counterbalance one another.[1] The usual method which is now employed is to determine the manganese colorimetrically after oxidation to permanganic acid. Various means of effecting this oxidation have been employed. The oldest method is the oxidation of the manganese in nitric acid solution by the addition of lead peroxide.[2] This material proved unsatisfactory owing to the necessity for the removal of the excess of the lead peroxide, which settles very slowly.

Acting on the suggestion of Marshall,[3] Walters[4] substituted ammonium persulphate for the lead peroxide. All of Walters' determinations were made on either steel, pig iron, or blast furnace cinders. This method was later adopted by Hillebrand[1] and Washington[5] for the determination of total manganese in rocks.

Essentially the method consists in decomposing the rock powder in a platinum basin by means of hydrofluoric and sulphuric acids, expelling the excess of hydrofluoric acid by repeated evaporation with small amounts of sulphuric acid, evaporating to almost dryness, diluting with 1 : 1 nitric acid, filtering.

and oxidizing the manganese to permanganic acid by the addition of ammonium persulphate. The permanganic acid solution is then diluted to a known volume and the color read against a solution of known strength in a colorimeter.

In applying this method to Nebraska soils, following the detailed directions of Washington[5] we have found that we could not obtain concordant results on duplicate determinations, the variation between duplicates being sometimes as much as 200 per cent. Brinton[6] has already noted that in some iron ores the treatment with sulphuric and hydrofluoric acids does not give complete extraction of the manganese, and we have found that this is the case with all of the soils which we have investigated. In most of these soils, three, and in some cases four, extractions with hydrofluoric and sulphuric acids were necessary before all of the manganese was obtained in solution. Inasmuch as each extraction requires nearly three hours, it will be seen that to accurately determine manganese in soils by this method is a very tedious operation. We have, therefore, endeavored to devise a method which is much more rapid, more accurate, and which requires less attention, and eliminates all fumes of hydrofluoric acid or sulphur trioxide. The smaller amount of platinum required in the process is also a decided advantage.

As an oxidizer we have used sodium bismuthate instead of ammonium persulphate, inasmuch as it gives a better oxidation, always giving the true permanganate color, while the persulphate oxidation often produces a reddish tint that is difficult to read accurately. Blair[7] and Brinton[6] seemed to recognize the superiority of the "bismuthate" oxidation by stating that "for samples containing not over 2 per cent of manganese the bismuthate is the most accurate method known." Walters[4] states that the persulphate oxidation does not always progress smoothly, for when the salt is dry "the reaction is very incomplete and irregular and not to be depended on," a fact that is not mentioned in the description of the method by Hillebrand or Washington. By

moistening the persulphate much more concordant results are obtained, but we have found that the bismuthate is much more reliable than the persulphate. In some instances we were unable to oxidize all of the manganese by means of ammonium per sulphate, but when these same solutions were reduced with sulphurous acid and reoxidized with bismuthate the correct percentage of manganese was obtained. The bismuthate method has the added advantage over the persulphate in that it is not necessary to add silver nitrate to catalyze the reaction.

EXPERIMENTAL

THE ESTIMATION OF MANGANESE IN SOILS BY WALTERS' METHOD.—The soil, which had been ground to pass thru bolting cloth of 0.01 mm. mesh, was treated with hydrofluoric and sulphuric acids as described by Washington[5] and the manganese determined in the extract. The first part of Table 1 shows the results which were obtained on eight different soils. Soil No. 3,490 was selected to determine whether or not all of the manganese was rendered soluble with one extraction, and it was found that in some instances four extractions were necessary to completely remove all traces of manganese. In those samples where several extractions were made, the total amount of manganese obtained was nearly a constant, but even in these there is too great an error for exact work, for, altho the maximum difference between duplicates is only 0.010 per cent, this error represents almost 10 per cent of the total manganese present.

THE ESTIMATION OF MANGANESE IN SOILS BY OUR METHOD.—One gram of soil is intimately mixed with four grams of manganese-free dry sodium carbonate and fused in a 20 c.c. platinum crucible over a blast lamp until the melt is quiet, usually after about ten minutes fusion. The liquid mass is then poured into a platinum basin and the basin is rotated in order to obtain the melt in a thin film, thus providing for more rapid solution. The melt and the crucible are then treated with about

100 c.c. of distilled water and heated on a water bath in either a platinum or a procelain dish* until the fused product is completely disintegrated. The crucible is then removed from the dish, any adhering solution washed off, and the mixture acidified with 130 c.c. of 35 per cent (by weight) sulphuric acid and diluted to 250 c.c. This excess of sulphuric acid is employed inasmuch as the oxidation progresses more rapidly and basic bismuth salts do not precipitate. The same results may be obtained when half of this quantity of acid is used but the oxidation requires several minutes boiling and the permanganic acid solution must be filtered thru asbestos in order to free the solution from precipitated bismuth salts. Should there be a heavy precipitate of silica at this point it is advisable to filter, using a Büchner funnel and filtering by suction. This is seldom necessary, however, for in most cases the silica does not precipitate to any extent, but merely produces a slight opalescence which does not interfere with the permanganate readings. One hundred cubic centimeters of this solution is then placed in a beaker and from 0.25 gram to 1 gram of sodium bismuthate added, depending on the quantity of manganese present. We have found that 0.25 gram is sufficient where the manganese content does not exceed 0.20 per cent. The oxidation mixture is then heated to boiling and the boiling continued until the liquid has the true permanganate tint. If there is any red coloration the boiling has not been continued long enough. The solution is then cooled and read in a colorimeter or in Nessler's glasses against a standard solution of permanganic acid which has been prepared by reducing a solution of potassium permanganate in 20 per cent sulphuric acid by the cautious addition of sulphurous acid, and reoxidizing with bismuthate. This standard solution should contain about 0.2 mgr. of MnO per 10 c.c. From the ratios thus obtained the quantity of manganese in the original sample

* Glass should not be used inasmuch as the alkali might attack the glass and dissolve out some of the manganese which is present in most laboratory glass, including Jena apparatus.[5]

is calculated. After a little practice, the complete operation can be carried out in an hour and a half, so that in this respect alone the method is greatly to be preferred.

When duplicate determinations are desired, only one fusion is necessary, for two separate oxidations may be taken from the total 250 c.c. In the data which are given in the last column of the table each figure represents a separate fusion and oxidation, and in the sixteen determinations, representing duplicate fusions on eight different soils, the maximum difference between duplicates amounts to only 0.002 per cent. No determinations were discarded in compiling this table.

Per cent of manganous oxide found by Walters' method as described by Washington.

Experiment	Soil number	MnO in 1st extraction	MnO in 2d extraction	MnO in 3d extraction	MnO in 4th extraction	Total MnO found	Per cent MnO found by our new method
1	3490	0.082	0.020	0.004	Trace	0.106	0.109
2	3490	0.080	0.027	0.005	?	0.112	0.111
3	3490	0.060	0.042	Trace	?	0.102	.....
4	3490	0.095	0.013	Trace	?	0.108	.....
5	3490	0.095	0.013	Trace	?	0.108	.....
6	3490	0.064	0.016	Not determined	.....	.....	.....
7	3490	0.046	0.029	Not determined	.....	.....	.....
8	3486	0.045	Not determined		.....	.....	0.107
9	3486	0.052	Not determined		.....	.....	0.105
10	3487	0.018	Not determined		.....	.....	0.111
11	3487	0.028	Not determined		.....	.....	0.110
12	3488	0.020	Not determined		.....	.....	0.111
13	3488	.....	.....		.....	.....	0.112
14	3489	0.025	Not determined		.....	.....	0.120
15	3489	0.031	Not determined		.....	.....	0.119
16	3491	0.044	Not determined		.....	.....	0.123
17	3491	0.044	Not determined		.....	.....	0.125
18	3483	0.060	Not determined		.....	.....	0.096
19	3483	0.060	Not determined		.....	.....	0.098
20	3459	0.033	Not determined		.....	.....	0.067
21	3459	.	.....		.....	.....	0.067

SUMMARY

1. Walters' method for the determination of manganese is not applicable to soils, in some instances four extractions on a one-gram sample with hydrofluoric and sulphuric acids being necessary before all of the manganese is obtained in solution.

2. When such soils are fused with sodium carbonate and the solution of this melt is acidified with sulphuric acid and oxidized by means of sodium bismuthate, all of the manganese is oxidized to permanganic acid, and may be easily estimated colori metrically.

3. We claim for this method greater rapidity, absence of irritating fumes, less danger of loss by spattering, more successful operation in inexperienced hands, duplicate determinations on a single sample of soil, and much greater accuracy.

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THE INHERITANCE OF THE LIGULE AND AURICLES OF CORN LEAVES

By R. A. Emerson

The membranous projection of the leaf sheath above the leaf blade in corn, known as the ligule, together with the somewhat leathery triangular connection between the sheath and blade, sometimes called the auricle, are so generally present in grasses that they are usually included in botanical characterizations of the grass family, tho they are not universal in this group. The only studies of the inheritance of the liguleless condition known to me are those reported with oats by Nilsson-Ehle[3] and by Wilson, the latter from a reference by Hurst.[2] So far as I am aware, the absence of the ligule and auricle has never before been reported for maize. The first corn plants lacking these leaf parts to come to my notice were found in one of my pedigree cultures grown at the Nebraska Experiment Station in 1910. No such plants have ever been found in any stock of my corn not related to that in which it was first seen. That the liguleless leaf character originated as a mutation in that stock of corn in that particular year is unquestionably not to be thought of. When, where, or how it originated I have no way of knowing, and as to its possible present distribution outside of my own cultures I am equally uninformed.

The family of corn in which this type was first seen contained seventeen plants, every one of which showed the peculiarity. This family was the progeny of a self-pollinated plant grown the preceding year. The nature of this 1909 parent plant with respect to the peculiarity in question was not observed, but, from what is now known of the inheritance of the liguleless condition, it is reasonably certain that the 1909 parent plant must have exhibited the abnormality. That so striking a modification of

the habit of growth of a plant as that caused by the absence of the leaf auricle (see fig. 1) should have passed unnoticed is explained by the fact that the plant showing it was enclosed in an individual cloth "tent" thruout the summer, a method of insuring self-pollination being tried experimentally at that time. Growing in the garden at the same time were six other plants from the same ear as that from which the parent plant of the 1910 liguleless family came. This was an open-pollinated ear of dent corn secured at the National Corn Exposition held in Omaha. These six sister plants (or half-sisters?) are all known to have had normal leaves. They were self-pollinated by hand in the usual way and three of them were represented by progenies among the 1910 families. On discovering the pure liguleless family in 1910, I examined these related families at once. Two of them were found to have both normal and liguleless plants, the combined numbers for the two families being 39 normal and 16 liguleless. The one other family had only normal leaved plants.

The facts noted above suggested at once that absence of ligule and auricle is a recessive trait and that the original ear from which all my liguleless families have come must have been borne on a normal leaved plant that was hybrid with respect to ligule and auricle. The facts already noted also indicated that the presence or absence of ligule and auricle in my strains of corn (unlike Nilsson-Ehle's oats) depends upon a single hereditary factor. These early indications have been borne out in later tests conducted both in the field during the summer of 1911 and in the greenhouse the past winter. Six liguleless plants have produced from self-pollination a total of 175 offspring, all liguleless. Four liguleless plants crossed with unrelated normal leaved plants have produced 103 individuals, all normal leaved. Twelve of these first generation hybrids yielded from self-pollination 572 normal leaved and 176 liguleless plants. One heterozygous normal leaved plant crossed with an unrelated homozygous normal plant produced four normal leaved offspring. On being self-pollinated,

two of the four bred true, producing 96 individuals, all with normal leaves, and the other two yielded both normal leaved and liguleless progeny, 61 of the former and 29 of the latter. Lumping together all families in which both types of leaf have occurred, we find a total of 672 normal leaved and 221 liguleless

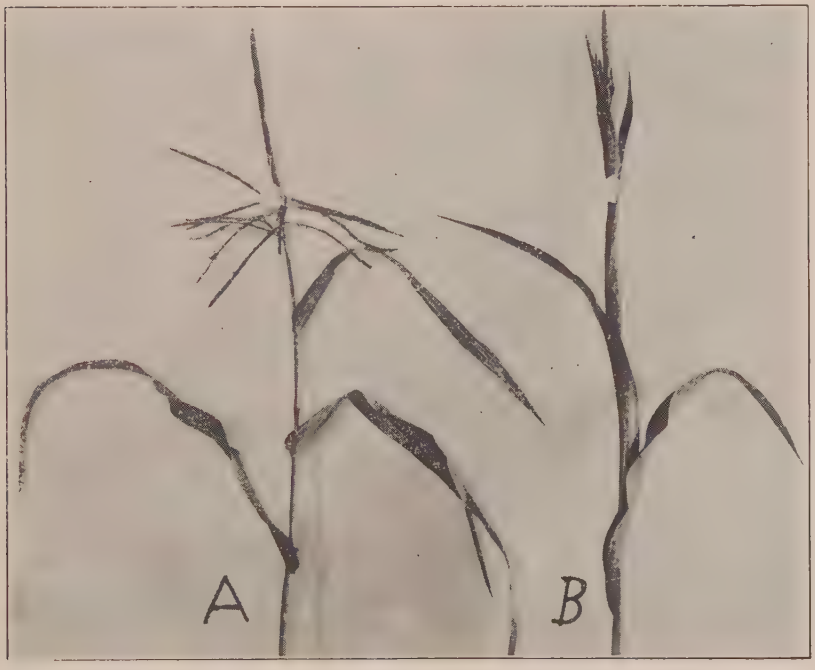

Fig. 1. *A*. Normal leaved corn plant. The auricles allow the leaves to stand out from the stalk. *B*. Liguleless leaved plant. The absence of auricles makes the leaves take an upright position.

leaved plants. To have given as nearly a 3 : 1 ratio as possible, the respective numbers need only to have been changed to 670 and 223.

The type of plant that I have here classed as liguleless lacks not only the ligule but also the auricle. In fact a few plants so classed have actually had a very poorly developed ligule, but the auricle, so far as I have been able to observe, has always been

missing. Whether the absence of the ligule proper is disadvantageous to the plant is somewhat questionable. Some botanists, who look upon every persistent plant character as necessarily serving some good purpose, have suggested that the ligule serves to keep the water collected by the leaf blade from running down

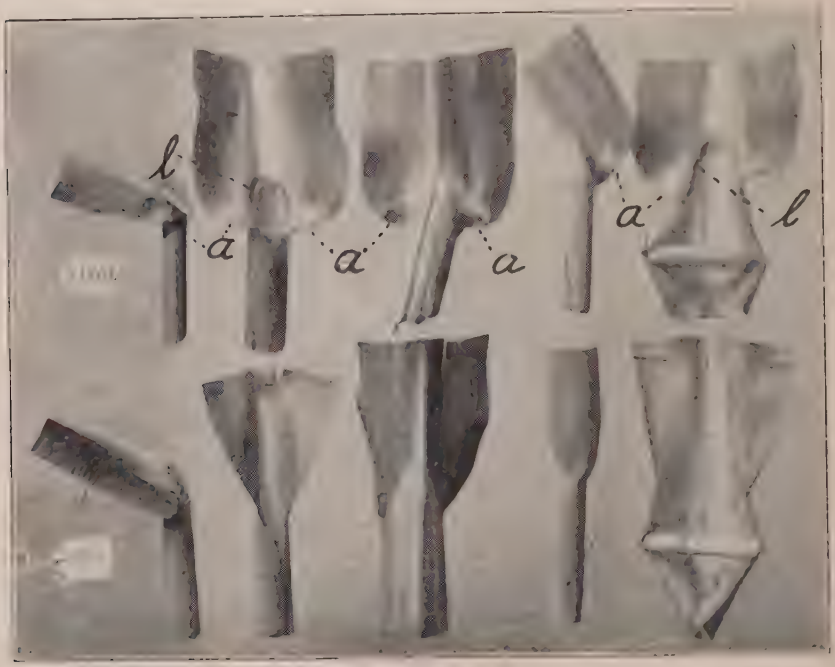

Fig. 2 Details of normal leaves (upper row) and of liguleless leaves (lower row). The auricles permit the blades to flatten out abruptly at the top of the sheath and also to bend away from the stalk at a sharp angle. The non-auriculate leaf is torn when the blade is bent abruptly backward (see extreme left of figure). *a*=auricle. *l*=ligule.

the stalk underneath the sheath where it might help to bring about decay. My own observations on liguleless corn are to the effect that the inside of the sheath is more often discolored, as if from incipient decay, than is the case when a well-developed ligule is present. In no case, however, have I found decay of the stalk or leaf sufficient to be of any material injury to the

plant—not even during the past summer when the plants were grown near Boston where they were exposed to moister conditions than is usually the case in Nebraska.

Fig. 3. One-sided arrangement of upper leaves, forming a hood for the tassel. *A* is a normal leaved pop-corn and *B* a liguleless leaved dent corn.

Whatever the effect of the liguleless condition upon the well-being of the plant, it apparently has nothing to do with the

peculiar habit of growth so characteristic of the liguleless type. (See fig. 1.) It is rather the absence of the auricle that makes the leaves stand so erect. In ordinary corn the leaf blade forms a more or less sharp angle with the sheath, the angle in any particular case depending much upon the size and stiffness of the midrib. It is the triangular shape of the auricle that makes possible the immediate flattening out of the leaf blade at the termination of the cylindrical sheath and that allows the blade to bend abruptly away from the stalk while the sheath still clasps it. In leaves that lack the auricle, the blade can neither be flattened out directly at the end of the sheath nor bent back sharply without either flattening out the sheath also or else tearing the blade away from the rolled up sheath. (See fig. 2.) It results therefore, in case of non-auriculate leaves, that not only the sheath but the lower part of the blade as well is rolled somewhat closely about the stalk and that the leaf as a whole assumes an upright position nearly parallel with the stalk, the tip of the leaf curving away gently if the blade is long and the midrib sufficiently flexible.

What effect this peculiar leaf habit may have upon the growth and productiveness of corn is not known. It seems reasonable that the lessened exposure of the leaves due to rolling about the stalk should reduce transpiration, and if so might possibly also retard photosynthesis. Further, the growth of the leaves up about the tassel might serve to protect the pollen from injury in extremely dry seasons but certainly causes it to rot in seasons of abundant rainfall, except when the upper leaves are arranged on one side of the tassel as described by Collins[1] in a certain Chinese corn. (See fig. 3.) In short, if this type of plant has any place in practical corn production it will doubtless be found where water is a limiting factor.

The stock in which the liguleless and non-auriculate type was first seen was a rather early dent corn of medium size. I now have crosses of it with sweet corn and pop-corn of various colors.

It has been combined with stocks that throw white seedlings and with others that contain the dwarf hermaphrodite abnormality. (See fig. 4.) So far, no definite correlation has been observed be-

Fig. 4. *A*, tall, normal leaved; *B*, tall, liguleless leaved; *C*, dwarf, normal leaved; *D*, dwarf, liguleless leaved plants from an F_2 family. The ratio approximated is 9 : 3 : 3 : 1.

tween ligulelessness and any other character except that of the non-auriculate condition, and these two conditions may, of course, be due to a single hereditary factor. The sharpness with which the non-auriculate condition segregates out in second generation hybrids and its inheritance independent of several common char-

acters in corn would make it possible to combine it with various commercial types of corn if it should prove a desirable character for particular localities and also would make it easy to rid a strain of it should it prove disadvantageous in certain environments.

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THE INHERITANCE OF CERTAIN FORMS OF CHLOROPHYLL REDUCTION IN CORN LEAVES

By R. A. Emerson

The presence of chlorophyll in the leaves of corn, and indeed of all grasses as well as of most other flowering plants, is so nearly universal that few perhaps have thought of it as a character that is inherited in accordance with a definite law any more than that the roots of these same plants are inherited "characters." While no one doubtless would deny the inheritance of chlorophyll, it is obviously impossible, just as with other characters, to determine experimentally the manner of its inheritance until plants lacking it are found. Such plants occur occasionally in corn, as they do also in many other kinds of the higher plants. Most such white plants of course perish as soon as the food stored in the seed is exhausted since they have no means of making food for themselves. Only such plants as have the ability to live as parasites or saprophytes can persist after having lost the power to produce chlorophyll.

From the fact that white corn plants always die within a few weeks of the time they appear and can not therefore reproduce themselves directly, it must not be inferred that their reappearance year after year is due to production anew by mutation each succeeding generation. Knowing, as we do now, that the absence of chlorophyll in corn is a simple Mendelian recessive, we see readily that a single mutation resulting in the loss of the ability to produce chlorophyll might account for all the white seedlings that have since occurred. If in the production of a single gamete there were lost the ability to start or to complete properly a series of reactions ending in the normal production of chlorophyll, this single gamete, in order to produce a plant, must unite with a

gamete that is normal in respect to chlorophyll production. Such a union would result ordinarily in a fully green plant not distinguishable from a homozygous green individual. If self-pollinated, 25 per cent of its progeny should be pure white and would of course perish; 25 per cent should be pure green, yielding only green offspring; and 50 per cent should be green but hybrid like their parent, yielding in turn, if selfed, progenies containing 25 per cent of white seedlings. But if the original hybrid-green mutant should be largely cross-pollinated by pure normal green plants, as would be most likely, white seedlings might not appear until the third or some later generation and would never occur of course except by the union of two germ cells both lacking the ability to bring about chlorophyll formation. And in the meantime the several hybrid green plants, tho normal themselves, would have been producing germ cells one-half of which lacked some factor necessary for chlorophyll formation and would thus have been scattering the abnormality broadcast. Tho I have observed the occurrence of white seedlings in many of my corn families, I can not say that any of these plants have been due to a mutation occurring in my pedigree cultures. All of them are readily traced back to a very few plants used in my original crosses as will be indicated more clearly in the account of the breeding experiments given below.

In 1909 a single corn plant was found to be prominently marked with longitudinal stripes of green and white varying greatly in breadth, very much like some of the variegated varieties of maize and other grasses sometimes grown as ornamental plants. This plant was self-pollinated and also crossed with a fully green plant. No record was made of the progenies of this plant in 1910 until the seedlings were a foot or more high, at which time it was found that there was a poor stand in case of the plants grown from selfed seed and a fairly good stand of plants grown from the crossed seed. Not a variegated plant was found in either lot—all were fully green. The following winter,

seeds from both of the two 1910 lots were germinated in the greenhouse. Again no striped plants were seen, but several pure white ones appeared along with the green ones. (See fig. 1.) These white plants of course all died in a few weeks owing to their inability to manufacture carbohydrate food. This sug

Fig. 1. Green and white corn seedlings in a greenhouse seed flat. The white seedlings had ceased growing before the photograph was taken and died within a few days afterward.

gested that the original variegated plant of 1909 was heterozygous for green and that green was not fully dominant to white in case of this one plant; that the 1910 progenies consisted in part of heterozygous plants in which, however, green was fully dominant; and that the poor stand of the 1910 lot grown from the selfed ear of the variegated plant was due to the occurrence of

many white plants and their subsequent destruction. The matter was tested at once by planting the remaining seeds from the selfed ear of the original variegated plant. Five green and three white seedlings resulted. Various tests were also made with seed from plants of the 1910 lot resulting from the cross of the variegated plant with a fully green plant. These tests resulted as expected in the appearance of both green and white seedlings in the progenies of some plants and only green seedlings in other cases. Numerous tests have since been made with this stock of corn and a large number of seedlings grown, all of which have been either fully green or fully white except eight individuals which have been prominently variegated like the original plant from which these families arose. Apparently in this stock of corn green is usually fully dominant, but occasionally is imperfectly so, resulting then in a variegated plant.

White seedlings have also occurred in stocks of corn unrelated to the families noted above. One of these cases is of particular interest. One of the original plants of this stock, itself fully green, was crossed with various pure green races, and of course produced nothing but fully green first-generation offspring. It was not, therefore, until white seedlings were found in several second-generation progenies, all tracing back to this same grandparent, that its real nature was indicated.

In all, white seedlings have now been recorded in forty-one distinct progenies, but the pedigrees of all these trace back to only five apparently unrelated stocks of corn. When all the forty one families that have shown white seedlings are considered together, it is found that they contained a total of 1,903 plants, 1,457 of which were green (including 9 prominently variegated plants) and 446 were white. Many of these records have been made in the greenhouse. The white seedlings can be distinguished from the green ones as soon as they appear and usually die in about three weeks from the time the seed is planted. In some lots, all derived from one of the five original stocks that

have produced white plants, the "white" seedlings have been yellowish-white at first, the older leaves soon becoming yellowish-green and later a fairly strong green. None of the greenish-white seedlings under observation has ever lived to mature tho it is not uncommon for them to live a week or two longer than the pure white seedlings, and one such plant lived to the age of seven weeks. While the two kinds of "whites" are doubtless distinct, their interrelations have not been carefully studied as yet.*

While the nature of this abnormality renders it impossible to produce a strain that breeds true white and that can be crossed directly with true green strains, it is none the less evident, as suggested by East and Hays,[7] that the white seedlings are homozygous recessives. The green plants in any family in which white seedlings occur must then be of two sorts, one homozygous green, producing nothing but green offspring, the other heterozygous green (sometimes variegated), yielding on self-pollination about three green seedlings to one white one. There should of course be one pure green to two hybrid green plants. Of 43 plants tested from such families, 15 have been found to breed true to the green color and 28 have produced both green and white seedlings. Similarly, of plants from all-green families resulting from a cross of pure green plants with hybrid green ones, half should breed true green and half produce both green and white seedlings. Of 17 plants tested from such families, 9 have produced green plants only and 8 have yielded both greens and whites.

Mention has been made above of the occurrence of prominently variegated plants in some families that produce about 25 per cent of white seedlings. Such plants are usually noticeably striped

* A preliminary examination of these pure white and yellowish white seedlings indicates that from the former plastids may be entirely absent while in the latter they are apparently present from the first, tho fewer in number and much smaller than the plastids of normal green seedlings or of seedlings made yellowish by being grown in darkness. These studies are being conducted at my suggestion by Mr. F. C. Miles, a graduate student in genetics. The study includes an examination of both fresh material and of paraffin sections stained with Lichtgrün, iodin green, Delafield's haematoxylin, or acid fuchsin.

from the beginning and may show less or more white as they grow larger. In the latter case they may eventually die thru their inability to produce a sufficient amount of food. Only two of these variegated plants have been tested and they both proved to be heterozygous for green color, having produced full greens and pure whites in the next generation. Whether any such prominently variegated plants are ever homozygous for green color can not be said. They occur only very rarely, only 9 having been seen in progenies totaling over 1,900 individuals, over 1,450 of which were green and in which therefore nearly 1,000 should have been heterozygous for green. It is perhaps worthy of note that eight of the nine variegated plants appeared in one stock and only one such plant in an unrelated stock. It might be thought from this that the variegation here seen is a pattern character independent of the presence of green color. Considering only those families in which variegated plants occurred, there were 175 fully green plants and 9 variegated ones, or a ratio of 19.4 : 1. The ratio in the several families varied from 9 : 1 to 26 : 1. This suggests the possibility of there being two factors such that only in the absence of both is the plant variegated. Such a condition would be expected to give ratios approximating 16 : 1, as found true for certain colors in wheat and oats by Nilsson-Ehle[8] and for yellow endosperm in corn by East.[6] If this were true with respect to variegation in these corn families, some families showing 3 : 1 ratios are to be expected, and indeed one such family is known, and is discussed later in this paper. The one fact, however, that positively disproves this hypothesis for these cases of variegation is that the two variegated plants tested were not homozygous for variegation, but on the contrary one of them produced only two variegated plants in a progeny of twenty while the other produced no variegated offspring in a somewhat larger progeny.

An apparently different sort of variegation was observed in one 1911 family of corn not related, so far as known, to the families that produced the eight variegated plants referred to

above. The family consisted of 118 individuals, 30 of which were apparently pure white and of course died as seedlings. The other 88 plants were examined carefully for variegated individuals while still small and again somewhat later without the discovery

Fig. 2. Inconspicuously variegated leaves—a single narrow white stripe on each leaf.

of a single variegated plant. At blossoming time, however, it was found that a considerable number of these supposedly fully green plants had one or more leaves very indistinctly variegated with pale green and white. In no case was the variegation at all conspicuous and in some cases only a single very narrow white stripe could be found on a whole plant. (See fig. 2.) An

accurate classification of such material is almost impossible, since a plant, thru some injury to the only variegated leaf it has, might be classed as fully green. Of the 88 plants that survived in this family, 22 were classed as inconspicuously variegated, while on the other 66 plants no striped leaves could be found. The observed numbers, 66 fully green, 22 slightly striped, and 30 white, give almost exactly the common dihybrid ratio of 9 : 3 : 4, suggesting that in this family presence of green color and inconspicuous variegation may be distinct characters independently inherited. If this is true, variegation here must be recessive to self color (green) and should therefore breed true. Another generation must be grown before the matter can be cleared up. The question cannot be determined from greenhouse cultures because the seedlings show no stripes.

A bit of evidence indicating that this inconspicuous variegation may not be due to heterozygosis of green, as seems to be true of the prominent variegation occurring rarely in another stock noted above, is afforded by several cultures of seedlings germinated in the greenhouse during the past winter. From the inconspicuously variegated plants of the family under consideration, ten progenies were started, eight of which contained white seedlings and *two of which had only green seedlings.* Similarly, from supposedly fully green plants of the same family four progenies were grown, three of which yielded only green seedlings and one both green and white seedlings. If no mistakes were made in classing as variegated two of the plants that yielded wholly green progenies—and such a mistake while not impossible is less likely than the opposite mistake of classing a slightly variegated plant as fully green—certainly this inconspicuous variegation is not an indication of heterozygosis of green color.

It is well known that there are varieties of corn that have prominently variegated leaves and that breed true to that condition. Such varieties are not uncommonly grown as ornamentals by gardeners. Only two such sorts have been included

Fig. 3. Prominently variegated leaves of *Zea Japonica*—variable stripes of green, pale green, and white.

in my cultures. The seedlings are usually unmistakably, tho never prominently, variegated. The older plants have prominent longitudinal stripes of green, white, or yellowish, and pale green of variable width and length.* (See fig. 3.) A single cross between one of these striped varieties, known as *Zea Japonica,* and a fully green sort produced 34 seedlings all fully green in the seedling stage. Three of these were grown to maturity in the greenhouse without the appearance of a single stripe. No second generation has been grown but the indications are that this type of variegation is a recessive character.

A single family of corn, distantly related to the stock in which the first variegated plant seen in my cultures occurred, was found to contain 57 apparently fully green plants, 14 variegated ones, and 2 that were recorded as white. The latter may, however, have shown merely an extreme form of variegation, since the variegated plants varied from green with narrow white stripes to white with a few narrow green stripes. The parent of this family was a fully green plant. This would suggest that, in this case, variegation is a recessive character and that the segregation is possibly of the simple three-to-one sort. Another family closely related to this one contained 55 fully green plants and 3 prominently variegated ones. This suggests that perhaps here two independent factors are concerned, either one of which may bring about the fully green condition, so that variegation can occur only in the absence of both. More evidence, however, is needed before any conclusion can be reached regarding the inheritance of this character.

The fact that the variegated plants of these two families are prominently striped even in the seedling stage, while the seedlings of the variegated varieties grown by me are not noticeably striped tho the mature plants of all are very similar, suggests that dis-

* Preparations made by Mr. Miles suggest that the cells of the yellowish white stripes contain very few, if any, plastids and that the pale green areas are apparently due to colorless or nearly colorless layers of cells thru which the cells with normal chloroplasts are seen.

tinct types of variegation may be concerned. It is of course equally possible that all the types of variegation noted in this paper may be due to the same thing and that the characteristic

Fig. 4. *A*. Corn leaf showing regular stripes of dark green about the veins, and of pale green between them. *B*. Spots of yellowish-green coalescing in rows to form broken yellowish stripes between the veins.

differences in appearance are due to the presence of and interaction with other diverse characters in the several stocks.

A distinct type of striping, not variegation, was seen in one family of corn in 1911. The stripes run lengthwise of the leaves, but, instead of varying greatly in breadth and even in length as is true of variegated leaves, are all uniformly narrow and ex-

tend thruout the entire length of the leaves. (See fig. 4, *A*.) The regions traversed by fibro-vascular bundles are uniformly dark green like normal leaves while the regions between the bundles are uniformly very pale green. There were in this family 112 plants with normal green leaves and only 19 plants with striped leaves at the time the plants were full grown. A number of plants died while small. The striped leaved plants were somewhat smaller and also noticeably later in blossoming than the normal plants. The height of the striped plants averaged 109 centimeters while that of the normal plants was 129 centimeters. The average number of days from planting to blossoming time were 81.4 for the striped plants and 68.3 for the normal plants. No examination was made of the chlorophyll of the light colored stripes, but there was apparently a deficiency of it and the striped plants seemed to be in a more or less pathological condition thruout their period of growth.

The numbers given above afford the only indication I have of the manner of inheritance of this abnormality except that no striping was noted in the parent of this family and that it was probably of normal green color. Taken together these facts suggest that this striping is a simple Mendelian recessive. That the character is really inherited rather than due to a "diseased" condition of a few of the plants of the 1911 family is made probable from the fact that two cultures grown in different parts of the field from the same parent plant both contained the striped plants in about the same percentage while no similarly striped plants occurred in any other family in either part of the field.

In 1910 twenty-four plants of a light yellowish-green color were found in a small plat of silage corn. They resembled in color the so-called "golden" varieties of various ornamental shrubs. That they possessed considerable chlorophyll was indicated by their color and by the fact that all twenty-four plants grew to nearly normal height and produced pollen in abundance. That they were deficient in chlorophyll was indicated not only by

their color but also from the fact that not one of the twenty-four plants was able to produce a single ear of corn. Obviously no progenies could be grown from these plants. A fair ear was found, however, on a similar yellow plant in another field and the progeny of this open fertilized plant contained a considerable percentage of yellow plants in 1911, thus indicating the hereditary nature of the yellow character. Two plants of pure green families were crossed with pollen from one of the barren yellow plants of 1910, and the plants of the 1911 progenies, a total of 137, were all fully green, thus indicating that this type of chlorophyll reduction, like those already considered, is a recessive character. No examination of the chloroplasts of this yellow corn has been made.

Mention should also be made of a peculiarly spotted and striped appearance of the leaves of certain maize families noticed first in 1911. At about the time of blossoming, or somewhat earlier, the leaves began to show numerous small, roundish, yellow-green spots. In some cases the spots remained distinct thruout the remainder of the life of the plant, but in many cases they coalesced in rows to form broken stripes between the veins. (See fig. 4, *B*.) Not infrequently the yellowish green tissue died before the plants matured. Nothing is known of the inheritance of this peculiarity and it would therefore not have been mentioned here had it not been for these facts: First, that it was limited definitely to certain families as grown in the summer of 1911, and second, that the plants grown in the greenhouse during the following winter from seed of spotted plants all developed the same spotted appearance, thus indicating that this condition may be inherited. No parasitic organism has been found in connection with the yellow spots by the Department of Agricultural Botany, to which the matter was referred. No attempt has been made to determine whether the spotted condition can be transferred to healthy plants by inoculation as in the case of "enzymatic" diseases.

In conclusion it may be said that reduction of chlorophyll in corn is of several kinds. *First,* the entire absence of chlorophyll and apparently even of plastids, resulting in the early death of the seedlings. It behaves in inheritance as a simple Mendelian recessive. Here the heterozygous plants are usually fully green but in rare cases may be prominently variegated white and green. *Second,* the almost complete absence of chlorophyll and a marked reduction in plastids resulting in yellowish-white seedlings that may later become more or less greenish, but which so far as observed never live more than a month or two. This is also a simple Mendelian recessive. *Third,* apparently a partial reduction of chlorophyll in the growing and mature plant, resulting in a yellowish-green color not noticeable in the seedling stage. Such plants rarely mature good ears but produce pollen in abundance. The character is certainly not a dominant one. Its inheritance has not been fully investigated. *Fourth,* the entire or partial absence of chlorophyll from a few very narrow streaks in some leaves. This results in a type of very inconspicuous variegation. Tho occurring in a family that produced pure whites, it is probably not due to heterozygosis of green. It is apparently a recessive character. *Fifth,* the partial or complete absence of chlorophyll from more or less broad and elongated areas of the leaf resulting in prominent longitudinal stripes (variegation) of green, pale green, and white. Apparently this is a Mendelian recessive. In some cases it may be able to appear only in the absence of both of two positive factors. Perhaps more than one type of variegation is included here. *Sixth,* a definite narrow striping of the leaf, not a form of variegation. In the region of the fibrovascular bundles, the leaf is dark green, while between the bundles are narrow stripes of very pale green. These striped plants are uniformly smaller and later than fully green plants of the same family. The condition is apparently a Mendelian recessive. *Seventh,* the appearance of yellowish spots coalescing into rows between the veins of the leaf and sometimes causing (?)

the death of the yellowish tissue. This is apparently not due to a parasitic organism. It has appeared in two successive generations of the same stock of corn, suggesting that it may be an inherited character.

Almost nothing is known as yet of the possible interrelations of these different forms of chlorophyll reduction. In so far as their inheritance has been carefully studied, they have been shown to be Mendelian recessives.

The behavior of the prominently variegated plants, which occur rarely in families made up of about three fully green plants to one white plant and which are, at least in some cases, heterozygous for green color, is of particular interest. In some respects their behavior resembles that observed by Baur[2] in case of a variegated (mosaic) *Pelargonium*, but in essential features it is fundamentally different. Mosaic pelargoniums Baur found to vary, just as these variegated corn plants do, from nearly white to nearly green, some branches being wholly green, some wholly white, and some in part white and in part green (sectoral chimeras). Reciprocal crosses between white and green branches of a mosaic plant, or between white branches and any green race, were all mosaics of white and green. Selfed flowers on mosaic parts of these plants produced wholly green and wholly white seedlings like the variegated corn plants here under consideration, but the ratios in case of *Pelargonium* were extremely variable, whereas with maize they always approximate 3 : 1. Moreover the green pelargonium plants thus produced are always homozygous, while in case of corn about two-thirds of them are heterozygous. With *Pelargonium* selfed seeds from green branches of mosaic plants always breed true green and seeds from white branches bred true white, a matter that I have not been able to test in case of corn. In short, while the mosaic of green and white in *Pelargonium* and in this particular lot of corn is apparently due to heterozygosis, the behavior in later generations shows the case of corn to be merely simple Mendelian in-

heritance, while the *Pelargonium* is one of only two certainly known cases of non-Mendelian inheritance that have been reported.

It is interesting to add further that Baur has reported another case of leaf color in *Pelargonium* that mendelizes typically. The case concerns crosses of yellow leaved forms (not capable of independent existence) with green leaved sorts, in which F_1 is "golden" leaved and F_2 is made up of the three types in the monohybrid ratio 1 : 2 : 1. Other cases of Mendelian inheritance of green color have also been reported for *Antirrhinum* by Baur.[1] There is as yet no indication that in *Zea* there is to be found any sort of non-mendelian inheritance of green color, either like that noted above for *Pelargonium* (Baur[2]) or like that observed by Correns[3, 4] in *Mirabilis Jalapa,* where both the green and the white conditions are inherited thru the mother only.

No opportunity has as yet occurred to determine the behavior of fully green shoots of true-breeding, variegated maize plants. Whether they will be found to be heterozygous for green as Correns[3] found to be true in case of *Mirabilis* can not therefore be told.

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THE MOISTURE CONTENT OF FIELD SOILS UNDER DIFFERENT TREATMENTS

By P. B. Barker

The soil moisture data here presented are a compilation of figures procured from the fields of the University Farm during the past three years. Soil moisture investigations have been in progress at the Experiment Station for five years and an immense amount of data has been collected from which much information may be ascertained concerning the water in the soil.

The soils experimented with are mostly silt loams and known as Marshall silt loams. According to the Lancaster Soil Survey Sheet, over 60 per cent of Lancaster county is composed of this type of soil. This type contains more than 55 per cent silt and from 10 per cent to 25 per cent clay.

It was thought advisable to present the moisture content of only the fields of corn, small grains, and alfalfa, and one field which was summer tilled. The data here presented are, for sake of brevity, further limited to the months of June, July, and August.

The moisture content of the fields is ascertained for each of the uppermost six feet at least twice per month—once at the beginning and once near the middle of each month. It is thought best to present, in this paper, only the data from the six-foot sampling made about the first of the month. Besides the six-foot samplings, several two-foot samplings were made at intervals of two or three days, which permit of more detailed study of the soil moisture.

The samples are taken by means of a set of soil tubes. This enables the operator to obtain representative samples from each foot.

It is the practice at the Station to obtain composite samples from each foot in depth by taking samples from several places in each field and mixing the corresponding samples from each

foot section. For instance, a composite set of samples from field A may represent samples taken at several different places in order to obtain samples that are representative of the field. The samples taken at the several places for the first foot are thoroly mixed and a small sample obtained. In the same way composite samples are obtained from each foot in depth of the field.

The samples are dried at 110° C. and the percentages computed, using water-free soil as the basis of calculation. Notes are taken on the appearance and condition of the crops at each sampling, thus correlating the condition of the crop with the moisture content of the soil.

The following tables represent the moisture content in the corn, small grain, alfalfa, and summer tilled fields for each of the uppermost six feet.

Each of the columns headed June, July, and August is an average of the moisture contents at the beginning of each respective month in 1909, 1910, and 1911. For instance, the column headed June represents the average of the moisture content at the beginning of June for the three years mentioned above.

MOISTURE CONTENT OF FIELD SOILS

	SMALL GRAINS			ALFALFA		
Depth	June	July	August	June	July	August
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	19.19	17.61	15.18	20.90	21.95	19.48
2	19.70	18.96	18.42	25.42	21.81	21.25
3	21.07	19.51	18.13	24.97	19.94	20.71
4	19.69	19.00	17.86	20.86	17.42	18.08
5	24.69	22.60	21.01	20.65	17.91	17.22
6	25.90	23.02	24.97	20.39	18.19	17.39

	CORN				SUMMER TILLAGE		
Depth	May	June	July	August	June	July	August
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	22.70	28.49	23.72	18.83	26.65	24.75	25.95
2	28.80	28.28	27.36	21.32	27.95	25.90	25.90
3	.....	23.56	25.66	20.91	23.85	23.60	24.50
4	.....	22.26	22.76	21.31	23.70	25.00	23.70
5	.....	23.48	23.72	24.26	26.90	25.85	25.40
6	.....	26.19	24.97	25.74	25.85	26.10	26 25

It is interesting to correlate the size and conditions of the various crops with the moisture content of the respective fields at the time of sampling and, consequently, the following notes should accompany the tables:

CORN.

June 10. The corn was usually about six inches high at this time and had been cultivated once.

July 1 to 12. The corn is usually growing very rapidly at this time of the year and a few days may cause a great difference in the height, but it ranges from about 2 to 5 feet during the first half of July. The roots are thoroly established and consequently the crop may be transpiring one or two inches of water per week.

August 3 to 12. The height of the corn varied during the early part of August from about 10 feet in 1910 to 6 feet in 1911.

SMALL GRAINS

June 10. The wheat was about 2½ to 3 feet high June 10 for each of the past three years and consequently was using a large amount of water. The oats were about sixteen inches high at this time of the year. The small grain crops were growing nicely at this time for the first two years, while the surface soils were rather dry at this time of the year in 1911 and the lower leaves were falling off.

July 1 to 15. The wheat and oats were harvested from the 1st to the 15th of July. The upper three feet were usually rather dry.

August 1. The wheat and oat land on which these soil moisture experiments were conducted was disked and plowed about August 1. The stubble fields are usually treated differently in order to ascertain the effects of the different treatments on the moisture content.

ALFALFA

June 10. The first cutting of alfalfa is usually done near this time, when it is generally about 18 inches high.

July 1 to 12. This is approximately the time of the second cutting of alfalfa. The alfalfa usually makes a large growth during the months of June and July.

August 3 to 15. The third cutting of alfalfa is generally made about this time of the year.

A FEW NOTES CONCERNING THE ACCOMPANYING TABLES

1. The summer-tilled fields contain more water at all depths during June, July, and August for the years 1909, 1910, and 1911 than those producing wheat, oats, or alfalfa.

2. The moisture content is also comparatively uniform in the upper six feet and thruout the growing season.

3. The moisture data shown in the columns under June and July in the corn table are similar to the amounts in the summer-tilled fields, largely because the corn does not begin to use excessive quantities of water until July. It may be well to remind the reader again that the moisture contents here shown were ascertained at the beginning of the various months and consequently the percentages of moisture in the July column represent the conditions for the latter part of June and the early part of July.

4. The small grain crops contain the least percentages of moisture in the upper four feet in June, July, and August for the years under consideration.

5. The alfalfa and brome grass fields contain a lower per cent of moisture in the fifth and sixth feet than any of the other fields represented in the tables. They contain a trifle more water in the upper three feet than the small grain fields.

6. The moisture content of the small grain fields increases with the depth in the upper six feet, while the moisture content of the alfalfa fields decreases with depth from the second foot.

7. The moisture content of the cornfield decreases from the second foot to the fifth, when it begins to increase.

8. It is evident from a comparison of the tables that transpiration is a very important factor in causing a reduction in moisture content of soils.

9. The loss of water due to direct evaporation from the surface of the soil is a very small factor after the water becomes thoroly distributed in the soil.

According to the Rothamsted Experiment Station, about 50 per cent of the rainfall is evaporated under England's conditions and no doubt a large proportion of it is lost thru evaporation under Nebraska conditions when no vegetation is growing on the land. But the loss takes place mostly when the surface soil is very wet, before the moisture is thoroly distributed thruout the soil, and before the soil is in a good tillable condition.

TESTS OF CORN PLANTERS WITH GRADED CORN

By L. W. Chase and C. F. Chase*

Of late years there has been much said and published about the accuracy of drop of corn planters, the conditions influencing it, and its effect upon the resulting crop. The questions that have arisen are, shall we use the edge-selection or round-hole planter plates, and shall we grade our seed corn with a corn grader, by hand, or not at all? The work recorded was undertaken in an attempt to answer these questions.

Early experimenters found the kernels from both the butt and the tip ends of the seed corn ear to produce as well as those taken from the middle, provided their germinating power was not injured. Also, it is evident that the grader can not select the strong kernels from the weak further than by removing a few defective ones, which can be as easily removed with the fanning mill. The tests herein tabulated are purely mechanical and show how the removal of the irregular shaped kernels will influence the accuracy of drop of the planter. (By accuracy of drop is meant the placing of the exact number of kernels in each hill which the operator of the planter desires.)

Before starting the work a circular letter was mailed to the corn experts of some of the principal corn producing states. Eight questions bearing more or less upon the use of the corn planter and its effect upon the resulting yield of corn were asked. Questions and replies were as follows:

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Questions	Replies			
	1	2	3	4
1. If all the planters in your state planted accurately, how much would it increase the yield?	No evidence.	Don't know and do not like to guess.	Ten bushels.	10 per cent.
2. If a planter drops the correct number of kernels per acre, but drops from one to five kernels per hill with, say, 50 per cent containing three kernels, how much will it affect the yield, if any?	Two years' work indicate the yield would not be materially affected, provided the number of plants per acre remain the same.	Don't know how much, but it will make a difference.	Perhaps three or four bushels.	(Indefinite answer.)
3. How many kernels should be planted on an average acre, providing 95 per cent of them produce a stalk?	10,000 to 16,000 on fertile soil. 7,000 to 12,000 on medium soil.	Depends on quality of soil, variety of corn, etc.	10,800.	Rows 42 inches and kernels 15 to 18 inches apart, one to a hill.
4 What per cent of the kernels planted produce stalks under average conditions?	80 to 85 per cent.	Depends largely on viability and the crows.	60 per cent.	75 to 85 per cent.
5. How deep should corn be planted?	Depends—deep enough to insure moisture and good germination.	Depends on several conditions.	One and a half to two inches.	Varies. Average two inches.

Questions	Replies			
	1	2	3	4
6. How far apart should the rows be to produce the best results?	....	Same as 5.	Three feet and six inches.	Three feet and six inches.
7. Which is the more satisfactory, corn planted in hills or in drills, the hills being the same distance apart as the rows and both top planted?	Hills, because of cultivation.	Usually hill planting is preferable, because it can be cultivated both ways, making it easier to cope with weeds.	Planted in hills.	The method of planting the corn in drills has given the best results at this Station.
8. What is your opinion of the furrow opener?	Good for light soils. Its heavy draft is objectionable.	Usually a good thing if coupled with discretion.	It gets the kernel down into the surface soil which has been turned under (a more favorable seed-bed) and probably aids cultivation.	We have carried on extensive experiments with the disk furrow opener and in every case this has given increased results.
Remarks	None.	Most of the above are useless questions, as each of half a dozen answers might be correct—depending upon conditions which are found to vary and are not the same two years at a time even in the same field.	These answers are of course more or less general, as we have never given any of it very close consideration.	None.

The above information is of especial interest to the careful observer and emphasizes the fact that each individual farmer must be the judge of his own conditions to a large extent.

It is of value in connection with this work in that it furnishes something of a foundation to work upon, something of an idea of the value of having corn and planters that will give an accurate drop and place each kernel in the ground exactly where it should be with respect to the other kernels, the surface of the ground, the moisture in the ground, the soil particles, etc. It is evident that this is not as important as it is generally supposed, the essential thing being to place the seed in moist ground with the soil firmly packed about it.

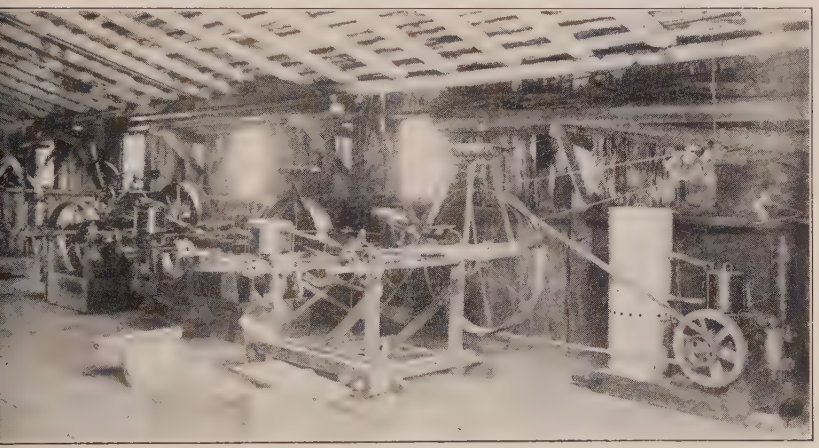
The corn for this experiment was taken from the general stock of seed corn of the Experiment Station Farm. The ears were taken as they came, that is, without any selection. Before shelling, the ears were divided into three grades, as follows: Those with very long kernels, those with kernels of medium length, and those with very short kernels. After this selection was made the ears were all butted and tipped, with the butt and tip kernels carefully reserved according to grade, weights being taken of each grade. The remaining corn was shelled and each grade weighed.

It is necessary to have the weights of each grade to know what per cent of the entire seed can be put into each particular grade. This of course is the important thing that the seed corn producer wishes to know. If the planter will plant a certain grade better than another or better than it would if it had not been graded at all, will it pay to sacrifice the otherwise good seed which the grading or grader has thrown out?

Four different kinds of drop were used and three different makes of planters. One of the planters was equipped with both the accumulative and full-hill drops. In both cases it was equipped with the round-hole planter plate. The other two planters had the edge-selection plate, but one had a continuous plate movement, the other intermittent. An accumulative-inter

mittent drop can be understood to be one where the hill is accumulated by having each cell in the planter plate deposit one kernel in the dropping tube as it passes, three cells to pass if it is set to plant three kernels to the hill, when the plate stops moving until the check wire throws the clutch on the dropping shaft again.

The planters were mounted on standards, one just ahead of



This cut shows the planters as they were set up for making the tests. The small rope passing thru the idler pulley over the engine is looped once about each planter wheel thru an idler pulley at the other end and back thru the check-heads of the planters. This rope has knots every three feet and six inches which act as the buttons on a check wire. The left planter wheels have been removed to make it easier to count the hills as they are dropped.

the other, as shown in the cut. A small endless cotton rope with a single loop knot every three feet and six inches and with washers threaded into the rope, one in front of each knot, was looped around the right-hand planter wheel of each planter, thru an idler pulley at the front, back thru the check-heads of the planters just as the check wire would go in the field and thru another idler pulley at the rear. A small gasoline engine was belted to the right-hand rear planter wheel and timed to make the

engine belt run at the rate of a little less than two and one-half miles per hour. It is readily seen that we have very nearly the same conditions which we would have in the field. Here we have the check wire moving instead of the planter. In the field this is reversed of course. Endless belt conveyors carried the kernels away from the planter shoe as they were dropped.

Preliminary tests of about one hundred hills were made with each kind of drop and each grade of corn to find which planter plate was best suited to each particular grade of corn. With the preliminary tests made and everything in readiness, a test of each of the three different grades of corn previously prepared was made in the following manner:

The engine was made to run the planters at the ordinary rate which they would run when working in the field. The endless rope was placed in the check-head of each planter in turn as the tests were made. This caused only one planter to drop at a time. One person sat at the rear of the planter shoe to count the kernels dropped for each hill as they came from the planter, another sat nearby and recorded the number as it was called out. The kernels dropped for one thousand or more hills were counted for each planter with each grade of corn, or in other words 4,000 hills were dropped and counted for each grade of corn. With one planter having the two kinds of drop the tests were duplicated, using each kind of drop in turn.

When the tests for the three grades were completed, this corn was all put together, giving us seed corn from which the butt and tip kernels had been removed. A test of this grade of seed was made on each of the four kinds of drop as before.

Another grade was obtained by putting these middle kernels thru the grader. That is, it gave us seed which was machine graded, butted and tipped. A test was made of this.

After these tests the butt and tip kernels and those which had been taken out by the grader were mixed with the rest and we

had our seed as it would have been had we shelled it from the whole ear. This was called "ungraded seed." A test was made as before.

The corn was then graded with one of the cylinder type of corn graders and weights were taken to show what part of the corn was removed in grading, and a test was made of the graded corn.

It was evident at the time that putting the corn thru the grader once did not grade it perfectly and it was decided to regrade the graded corn. A little more than half of the original corn was graded out by this time. This grade was tested.

The results obtained in the tests of the eight grades of corn and the four kinds of drops, comprising a count of 32,000 hills of corn, are recorded in the following table:

TABLE 1.—*Tests of graded corn and corn planters.*

Seed used	Planter	Plate	Per cent of hills having the number of kernels per hill shown (0 to 7)								Average number kernels per hill
			0	1	2	3	4	5	6	7	
Ungraded.	No. 1.....	A251	0.0	0.7	6.9	59.9	27.3	5.0	0.2	0.0	3.296
	No. 2.....	Small	0 0	2.4	17.2	65.8	13.5	1 1	0.0	0.0	2.937
	3, full hill..	414	0.0	1.2	19.5	56.7	21.3	1 3	0.0	0.0	3.020
	3, acc. drop.	9-16	0.0	5.6	27.0	45.2	19.5	2.5	0.2	0.0	2.869
Machine graded.	No. 1.....	A243	0.0	1.3	14.1	64.2	18.5	1.8	0.1	0.0	3.057
	No. 2.....	Small	0.0	1.7	18.1	68.0	11.4	0.8	0.0	0.0	2.915
	3, full hill..	414	0.6	1.2	14.9	57 8	24.4	1.1	0.0	0.0	3.075
	3, acc. drop.	17-32	0.2	7.7	34.4	44 6	11.4	1.7	0.0	0.0	2.644
Hand graded, butted, and tipped (long kernels).	No. 1.....	A243	0.0	0.4	8.6	70.0	18.4	2.5	0.1	0.0	3.143
	No. 2.....	Medium	0.0	1.5	17.1	68.4	12 3	0 7	0.0	0.0	2.936
	3, full hill..	414	0.2	2.3	28.5	51.0	16 6	1.4	0.0	0.0	2.855
	3, acc. drop.	9-16	1.6	11.7	34.3	43.0	8.4	0.9	0.0	0.1	2.480
Hand graded, butted, and tipped (medium kernels).	No. 1.....	A251	0.0	1.2	15.4	63.6	17.7	2.1	0.0	0.0	3 041
	No. 2.....	Small	0.0	0.1	6.5	69.1	21.7	2.6	0.0	0.0	3.201
	3, full hill..	414	0.1	0.2	6.9	52 8	36 4	3.4	0.2	0.0	3.361
	3, acc. drop.	9-16	0.1	4.0	22.8	57.2	15.1	1.7	0.0	0.1	2.866
Hand graded, butted, and tipped (short kernels).	No. 1.....	A251	0 0	0.1	1.4	58.7	31.3	7.5	1.0	0.0	3.477
	No. 2.....	Small	0.0	0.0	3.7	60.3	29.2	6.5	0.3	0.0	3.394
	3, full hill..	.....	0.0	2.0	22.7	59.3	15.9	0.1	0.0	0.0	2.894
	3, acc. drop.	17-32	0.1	1.7	16.5	56.5	21.6	3.4	0.2	0.0	3.089
Ungraded, butted, and tipped	No. 1.....	A251	0.1	1.0	8.9	62.6	23.9	3.3	0.2	0.0	3.199
	No. 2.....	Small	0.0	2.0	14.9	64.5	17.6	1.0	0.0	0.0	3.006
	3, full hill..	414	0.0	0.3	8.3	50.4	37.4	3.4	0.2	0.0	3.355
	3, acc. drop.	9-16	0 0	5.1	24.0	52.2	16.1	2.3	0.3	0.0	2.875

Machine graded, butted, and tipped.	No. 1.....	A251	0.0	0.15	3.7	67.2	25.1	3.9	0.0	0.0	3.289
	No. 2.....	Small	0.0	0.0	6.4	67.0	23.3	3.2	0.1	0.0	3.275
	3, full hill..	840	1.1	4.0	37.8	51.0	6.0	0.1	0.0	0.0	2.570
	3, acc. drop.	17-32	0.0	8.6	28.5	53.5	8.9	0.5	0.0	0.0	2.643
Twice machine graded.	No. 1.....	A243	0.0	0.2	8.0	70.6	19.0	2.1	0.1	0.0	3.151
	No. 2 ..	Small	0.0	0.4	11.2	63.3	23.3	1.8	0.0	0.0	3.143
	3, full hill..	414	0 0	0.2	7.3	58.5	30.3	3.5	0.2	0.0	3 302
	3, acc. drop.	9-16	0.2	4.5	25 9	55.9	12.3	1.1	0.1	0.0	2 793

A study of the above table will show the following points of interest:

1. Planter No. 2, which has an accumulative-continuous plate movement edge-selection drop, did not make a single hill out of its 8,000 without at least one or more kernels in it. Neither did it drop a hill with as many as seven kernels and in only one instance did it put as many as six kernels to a hill.

2. In every instance except one the edge-selection plates or planters, Nos. 1 and 2, gave a more nearly perfect drop than the round-hole plates gave.

3. The most perfect drop obtained was with the "twice machine graded" corn and the edge-selection-intermittent drop of planter No. 1.

4. The poorest drop was with the "hand graded, butted, and tipped (long kernels)" and the round-hole plate and accumulative drop. The number of hills in this test having two kernels was large, there being 343 out of the 1,000 hills counted, which indicates that the plate used was too small. Poor results were also obtained with this drop using machine graded corn, but this test indicates, as the other one does, that the plate was too small. Apparently the poorest work done, then, was with the ungraded corn and this planter, as shown in the fourth line of figures in the table.

To compare the round-hole with the edge-selection plate the following figures taken from the preceding table are given:

TABLE 2.—*Round-hole vs. edge-selection planter plates, showing per cent perfect drop obtained with different planters and grades of corn.*

Seed used	Edge-selection		Round-hole	
	Planter No. 1, intermittent plate movement, accumulative drop	Planter No 2, continuous plate movement, accumulative drop	Planter No. 3, intermittent plate movement, full hill drop	Planter No. 3, intermittent plate movement, accumulative drop
Ungraded	59.9	65.8	56.7	45.2
Machine graded	64.2	68.0	57.8	44.6
Hand graded, butted, and tipped (long kernels	70.0	68 4	51.0	43.0
Hand graded, butted, and tipped (medium kernels)	63.6	69.1	52.8	57.2
Hand graded, butted, and tipped (short kernels)	58.7	60.3	59.3	56.5
Ungraded, butted, and tipped	62.6	64.5	50.4	52.3
Machine graded, butted, and tipped	67.2	67.0	51.0	53.5
Twice machine graded	70.6	63.3	58.5	55.9
Average for each kind of drop	64.6	65.8	54.6	51.0
Average for each kind of plate	65.2		52.8	
Difference in favor of edge-selection plate	12.4 (per cent)			

Every corn grower and seed corn producer is anxious to know whether it pays to grade seed corn. The following table shows the amount of seed sacrificed and the more accurate drop obtained as a result of grading, and represents a count of 32,000 hills, which is the number of hills on nine acres with hills three feet and six inches apart, each way.

TABLE 3.—*Showing in per cent the portion of seed corn remaining after it has been graded in different ways and the accuracy of the drop from the grades thus obtained.*

Seed used	Pounds of corn			Per cent of entire corn	Per cent of perfect drop	Average number of kernels per hill	Number of kernels per acre (10,668 correct)
	Before grading	Butts and tips	After grading				
Ungraded	.....	.....	.....	100	56.9	3.031	10,770
Machine graded	40*	.....	27½	69	58.6	2.923	10,400
Hand graded, butted, and tipped (long kernels)	40	2¼	5½	16	58.1	2.853	10,130
Hand graded, butted, and tipped (medium kernels)	40	7	14¼	36	60.4	3.117	11,07 0
Hand graded, butted, and tipped (short kernels)	40	3½	7½	19	58.7	3.214	11,420
Ungraded, butted, and tipped	40	12¾	.....	78	57.4	3.109	11,070
Machine graded, butted, and tipped	29¼	12¾	17½	44	59.7	2.944	10,460
Twice machine graded	.....	.....	.....	50†	62.1	3.097	11,000

* These weights were not exactly as given; a few of the kernels being cracked in going thru the planters were graded out. They are given this way for comparison and the proportion is correct.

† The weights of this grade were misplaced, but it was known to be about half the original amount of corn.

We see by this table that it is better to grade the corn the second time with the grader than it is to butt and tip it and then grade it, a more accurate drop being obtained with the twice machine-graded than with the single grading and removal of butt and tip kernels, while the former did not remove as large a portion of the seed.

A study of the table shows also that it does not pay to separate the seed corn into the different lengths of kernels as was done in this experiment. Only a slightly better drop was obtained, at a sacrifice of a large portion of the seed.

It is shown that there is no relation between the accuracy of

drop and the total number of kernels per acre. The poorest drop of any was obtained with the ungraded corn and came the nearest to having the required number of kernels per acre, or the nearest to three kernels to the hill.

Five and two-tenths per cent more perfect drop was obtained with the carefully graded corn than with corn not graded at all. Considering the fact that the replies to our letter based on actual experiments and experience show little importance in having the exact number of kernels per hill, there would be some question as to the benefit derived from the grading of corn. We are not ready, however, to advise farmers to discard their corn graders. We know a more accurate drop is obtained from carefully graded corn. When the corn specialist shows conclusively that there is nothing gained by having a specified number of kernels to each hill providing there is at least one and not more than six in a hill and the right number to the acre, we will be ready to do away with the corn grader.

Acknowledgment is due W. P. Jeffords, who as a student worked with C. F. Chase in preparing the apparatus and conducting the tests.

SOIL MULCH

By H. J. Young

During the past two or three years the soil mulch has received considerable attention. Especially during the dry season of the past year did we hear of the great need of the soil mulch in conserving soil moisture. In 1910 an experiment was started to determine the efficiency of the loose soil mulch, as compared with the hard, bare surface, in retarding the evaporation of soil water. The experiment was extended to include a comparison of the soil water that was lost thru transpiration from the leaf surface of vegetation as compared with the evaporation from the mulched or unmulched soil.

Three plots were selected, one of which was hoed to the depth of two inches. The second was scraped in order to keep all vegetation down, but the surface was left as free from loose soil as possible. The third plot was allowed to grow up to volunteer vegetation.

In 1911 the experiment was repeated. The soil mulch, however, instead of being made with a hoe, was made by the use of a garden plow. This method insured a more uniform depth of mulch and caused a much better pulverization of the soil.

In preparing the following tables the data have been selected for dates as nearly alike as possible for the two years. Also, instead of averaging the results for the two years, they are tabulated separately for comparison and to show the efficiency of the mulch in the two years. All percentages are based upon the weight of water-free soil.

TABLE 1.—*Water in soil of cultivated plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13, 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	28.8	19.1	25 4	24.10	27.3	22.80	23.5	23 10	32.4	22.6	26.3	25 3
2	27.9	27.3	27.1	26.30	28.3	27.00	27.8	23.70	30.4	24.6	28 5	26.3
3	23.8	24.1	24.3	23.05	25.1	23.60	25.1	22.05	26.9	22.1	27.1	26.1
4	23.2	25.1	25.1	24.40	23.2	24.05	25.4	23.05	25.2	22.9	25.6	22.7
5	29.4	26.8	25.8	25.90	26.2	25.90	26.8	25 90	26.6	25 4	27 8	24.9
6	29.3	26.2	26.1	27.10	27.3	26.20	27.6	26.40	29.5	25.1	29.5	25.2
Av.	27.0	24.7	25.6	25.20	26 2	24.90	26.0	24.00	28 5	23.8	27.4	25.1

It will be noticed from the above table that the per cent of moisture changes but little during the entire season. The first foot, however, fluctuates more or less, due to rains. This moisture which has been evaporated from the upper six inches does not concern us so much at this time, as we are dealing with the moisture that is well established in the soil. In the second foot of soil in 1910, eliminating the data for September 2 (which are for samples taken a few days after an 8-inch rain and consequently very high), there is a variation of only 1.4 per cent in the moisture content. In the same foot in 1911 there was a variation of only 3.6 per cent. In the sixth foot in 1910 the variation was 3.4 per cent, and in 1911 2 per cent. Comparing the averages of the six feet, which does away with the small fluctuations, the moisture content of the entire plot during 1910 varied 2.9 per cent, and in 1911 it varied 1.4 per cent.

This does not mean that there was only 2.9 per cent of water evaporated from the plot in 1910 or 1.4 per cent in 1911, but only shows that the moisture content remained, under such treatment, almost constant. The data do not show how much water has been evaporated, but all small rains of half an inch or less are lost. It seems that this should be the active work of the mulch, but, as immediate cultivation after rains is disastrous to the

physical conditions of the soil, the mulch is not made in actual farm practice, until a large per cent of the water from such rains has evaporated.

TABLE 2.—*Water in soil of scraped plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13, 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	30.3	26.8	25.4	20.30	26.8	19.20	23.8	21.6	30.5	20.3	27.3	23.9
2	27.8	30.4	26.5	24.50	26.6	25.30	27.3	23.8	29.9	23.8	28.3	26.0
3	25.4	25.0	24.4	22.40	24.5	22.20	23.0	21.7	27.3	21.3	26.3	23.9
4	25.3	26.1	24.0	23.05	23.3	23.05	23.8	22.3	27.1	20.5	26.2	25.1
5	27.6	27.8	26.4	25.00	26.1	24.60	25.1	24.9	29.6	23.3	27.9	24.1
6	27.1	28.0	27.2	25.50	27.4	24.70	26.1	25.4	32.4	24.4	29.2	26.7
Av.	27.2	27.5	25.6	23.40	25.6	23.20	24.8	23.3	29.4	22.1	27.5	24.

In considering the data for the scraped plot it will be noticed that, due to rainfalls, the first foot fluctuates, as did the first foot of the cultivated plot. Comparing the data for this plot as we did those for the cultivated plot, we find a variation of 1.8 per cent in the second foot for 1910 and of 6.6 per cent in 1911. The sixth foot shows a variation of 3.1 per cent in 1910 and of 3.6 per cent in 1911. The variation in the average of the six feet in 1910 was 4.6 per cent and in 1911 5.4 per cent.

While this is a greater variation than was found in the cultivated plot, there is only 2.85 per cent difference, showing that the plot with the loose soil mulch was able to keep the moisture content 2.85 per cent nearer a constant during the season. It must be remembered that the weather conditions were such that the scraped plot during dry periods dried down to a depth of about two or three inches, and this dry layer appears to be almost as effective as the loose soil mulch. In all probability, if conditions had been such that a dry layer had not formed, the loose soil mulch would have shown a greater efficiency.

TABLE 3.—*Water in soil of untreated plot.*

Depth	June 13, 1910	June 16, 1911	June 28, 1910	June 28, 1911	July 13, 1910	July 14, 1911	Aug. 13, 1910	Aug. 18, 1911	Sept. 2, 1910	Aug. 30, 1911	Sept. 15, 1910	Sept. 13, 1911
Feet	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	29.00	26.8	14.5	13.9	19.8	11 9	13.4	19.6	32.80	12.8	27.90	16.2
2	25.80	28 4	21.0	21.2	19.2	14.8	18.2	16.0	30.25	15.0	30.20	14.2
3	24.10	24.5	24.6	20.0	20.4	15.3	16.6	14.1	27.80	13.5	25.80	15.9
4	25.10	27.5	25.3	24.0	25.4	20.4	16.9	13.4	26.10	13.8	24.10	14.8
5	25.50	27.0	25.3	27.4	26.5	26.8	19.1	15.0	23.10	16.8	20.60	20.8
6	27.05	27.1	26.7	25.8	27.3	26.7	25.3	20.2	24.70	18.7	24.75	18.1
Av.	26.10	26.8	22.9	22.0	23.1	19 3	18.2	16.4	27.40	15.1	25.50	18.3

The data for the untreated plot for the two years agree closely. The vegetation each year reached a height of about six feet. The data also show that the weeds have greatly reduced the moisture content at all depths. As the results are very similar for the two years, and as the 1911 data were not influenced by any heavy rainfalls of the four months, a comparison is made for but the one year. This plot during the four months varied in its moisture content as follows:

	Per cent.
1 foot	14.0
2 feet	14.2
3 feet	13.0
4 feet	14.1
5 feet	12.4
6 feet	9.0

The average departure from the original moisture content during the period of growth was 11.7 per cent as compared with 1.4 per cent in the cultivated plot and 6.4 per cent in the scraped plot. Thus it is easily seen that the vegetation has reduced the moisture content considerably and it appears that the transpiration of water from the leaf surface is a greater factor than is evaporation from the soil surface.

Thus, in conclusion, it may be said that the data for the two years 1910 and 1911, under the weather conditions that prevailed, show:

1. That a loose soil mulch was not much more effective than an unmulched soil in retarding the evaporation of the moisture that is well established in the soil.

2. That if a hard layer of soil dries out to the depth of two or three inches, it will act in the capacity of a mulch.

3. That much more of the established soil water is lost thru transpiration from the leaf surface of plants than is lost by evaporation from the soil surface.

THE NITROGEN CONTENT OF SOME NEBRASKA SOILS

By F. J. Alway and E. S. Bishop

In the following tables are given data on the nitrogen content of soil samples from the four chief soil areas of Nebraska—the Loess, the Glacial Drift, the High Plains, and the Sand Hills. The nitrogen content of the surface six inches varies from .306 to .018 per cent. Some of the samples of low nitrogen content are from unproductive soils, while others low in nitrogen are from soils of long-maintained productivity. In forming an opinion as to the sufficiency of the supply of nitrogen in the surface soil, one must consider not only from what part of the state the sample is taken, but also the type of soil and its composition in the virgin condition. While the maintenance of an adequate nitrogen supply is the chief chemical problem of soil fertility in Nebraska, the character of the subsoil, the presence of alkali, the slope of the land, and the amount and distribution of the water available for crops may entirely overshadow in importance even the nitrogen supply. In general, little information of value can be obtained from the chemical analysis of samples of soil as ordinarily taken by those who send them to the Experiment Station. In all cases samples should be taken from different places in the field in such a way as to show the character of the different soil layers within the first five feet of the surface at each place, and along with the samples should be sent a description of the layers as observed by the man while taking the samples. Usually more information of practical value can be secured from the field examination with an ordinary soil auger in the hands of an experienced person than can be obtained by weeks of laboratory investigation of samples.

Variation in the Composition of Individual Samples From the Same Field.—The data given in Table 1 show the variation

found in samples taken to the same depth and from the same field at various places in eastern Nebraska.

Four sets were taken from near Pawnee City. The first was from a virgin prairie of level upland loess, the next from one on a steep hillside, and having a soil of glacial drift—*till*. Adjacent to the latter was a field which had been under cultivation about 40 years without the application of manure or the growing of any leguminous crops. Five individual samples were taken from this with a view to obtaining those showing the extremes in the same field. In a blue-grass pasture within the limits of Pawnee City ten individual samples were taken, some from the level land in the valley and some from the valley slopes.

From a virgin prairie on loess soil near Genoa five individual samples were taken to a depth of six inches and a similar set was taken from an adjacent cornfield which had been continuously under cultivation for 30 years without the application of manure or the growing of any leguminous crop.

Another set of samples was taken from a small prairie field on the farm of Professor E. W. Hunt, near Syracuse. The field was on the side of a steep slope with only a small area at the base of the hill. Starting at the top of the hill eleven individual samples were taken at intervals of 30 feet. The nitrogen content was lowest at the steepest part of the slope and highest near the foot.

TABLE 1.—*Nitrogen content of individual soil samples from various parts of Nebraska.*

Series No. of soil sample	Near Pawnee City				Near Genoa		Near Syracuse
	Loess, prairie	Till, prairie	Till, cultivated field	Valley, pasture	Loess, prairie	Loess, cultivated field	Till, prairie
	1-12 ins.	1-12 ins.	1-12 ins.	1-6 ins.	1-6 ins.	1-6 ins.	1-12 ins.
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	.294	.227	.176	.288	.224	.181	.185
2	.294	.233	.161	.260	.242	.187	.183
3	.290	.248	.193	.306	.258	.176	.214
4	.278	.250	.166	.278	.257	.181	.168
5	.292	.229	.118	.231	.251	.178	.214
6				.260			.184
7				.293			.196
8				.274			.224
9				.293			.222
10				.240			.228
11							.223
Average	.290	.257	.163	.272	.246	.181	.204
Highest	.294	.250	.193	.306	.258	.187	.228
owest	.278	.227	.161	.231	.224	.176	.168
Difference	.016	.023	.032	.075	.034	.005	.060

ON THE LOESS AREA

IN LANCASTER COUNTY.—Soils Nos. 1776 to 1789 (see Table 2) were taken from four fields in the Salt Creek Valley, near Havelock, A and A′ being adjacent and B and B′ being adjacent. A and B were virgin prairies which had for many years been used for hay land and which had never been fertilized. A′ and B′ had been under cultivation for 20 and probably as long as 35 years, but their early history is not known. Both were so located that there was little probability of their ever having been manured. From each field two composite samples of the first six inches of soil were taken, using ten cores for each composite, and from each of three of these fields two composite samples of the first foot of soil were taken by means of an auger, combining five borings for each. In the case of the six-inch samples the weight of the cores was determined in order to show the relative compactness of the soil.

The difference in nitrogen between the prairie B and the cultivated field B′ was about the same for the foot section as for the six-inch section, indicating that the loss of nitrogen had been about the same for the second six inches as for the surface six inches. The samples from the prairie were, however, considerably lighter than those from the cultivated fields, showing that the soil was not as compact in the prairies as in the cultivated fields. Hence, in order to have had strictly comparable samples the depth to which these were taken should have been greater in the prairies than in the cultivated fields.

Soils Nos. 1790, 1791, and 1795 to 1801 inclusive were taken from two virgin prairies, the one near Tabitha Home, one mile south of the Experiment Station, and the other near Bethany. Samples to the same depth were taken from adjacent cultivated fields, both of which had been in cultivation for twenty years or more. Each sample analyzed was a composite of ten individual samples.

In October, 1908, nine composite samples were taken to a depth of six inches from the lowland portion of a field on the northeast corner of the Experiment Station Farm. The field was first plowed in 1892, and cropped with wheat and oats in 1893, 1894, and 1895, alfalfa being seeded with the oats in the last-mentioned year. From that time until it was plowed at the end of 1906 the field had been kept in alfalfa. The part from which the samples were taken was in corn in 1907 and 1908. At the time of sampling, the cornstalks had been removed and part of the field had been plowed. Each sample analyzed consisted of ten individual samples taken by means of a brass tube $1\frac{3}{8}$ inches in diameter and provided with a brass collar 6 inches from the end. The tube was forced into the ground until the collar rested firmly on the surface. The individual samples used for each composite were taken at intervals of 30 feet in such a way as to represent an area of one-fifth of an acre.

From an adjacent pasture on virgin prairie two similar composite samples, Nos. 1826 and 1827, were taken.

It is evident from the analyses that to form a reliable estimate of the relative amounts of nitrogen in the cultivated field and in the pasture the composites analyzed should be made up of a large number of individual samples, ten being far too few. Unlike the hayfield mentioned above, the pasture had more compact soil than the unplowed portion of the adjacent cultivated field.

Nos. 1735 to 1738 were taken from a field of virgin prairie and an adjacent cultivated field on the hill just south of the penitentiary near Lincoln. The soil is a sandy loam, formed partly from the underlying Dakota sandstone but mixed more or less with loess. Each of the samples analyzed was a composite of ten individual samples. In the case of each of these fields the two composite samples gave entirely concordant results.

In May, 1908, samples of soil, Nos. 1606, 1607, and 1608, to a depth of six inches were taken from a field of wheat on loess soil east of Bethany. Part of the field consisted of a level hilltop, part of a steep hill slope, and part of a comparatively level stretch at the foot of the hill. The surface soil on the level hilltop and at the base of the hill were of the ordinary dark color, while that on the slope had a yellow color. The wheat on the slope was badly stunted and gave little promise of producing grain, while there was a good growth on the hilltop and a very rank growth at the foot of the slope.

TABLE 2.—*Nitrogen content of surface soils from near Lincoln.*

Soil No.	Depth	Field	Nitrogen	Average weight of cores
	Inches		*Per cent*	*Grams*
FIELDS IN SALT CREEK VALLEY.				
1776	Surface six inches	A, Prairie	.250	121
1777	Surface six inches	A, Prairie	.240	129
1784	Surface six inches	B, Prairie	.225	124
1785	Surface six inches	B, Prairie	.223	115
1782	Surface foot	B, Prairie	.183	.....
1783	Surface foot	B, Prairie	.191	.....
1778	Surface six inches	A, Cultivated field	.196	152
1779	Surface six inches	A, Cultivated field	.194	154
1780	Surface foot	A, Cultivated field	.135	.....
1781	Surface foot	A, Cultivated field	.130	.....
1786	Surface six inches	B, Cultivated field	.195	135
1787	Surface six inches	B, Cultivated field	.194	134
1788	Surface foot	B, Cultivated field	.145	.....
1789	Surface foot	B, Cultivated field	.150	.....
FIELDS ON UPLAND NEAR EXPERIMENT STATION FARM.				
1790	Surface six inches	Prairie near Tabitha Home	.280	.....
1791	Surface six inches	Prairie near Tabitha Home	.277	.....
1792	Surface six inches	Prairie near Tabitha Home	.281	.....
1794	Surface six inches	Adjacent cultivated field	.192	.....
1795	Surface six inches	Prairie near Bethany	.240	.....
1796	Surface six inches	Prairie near Bethany	.256	.....
1797	Surface six inches	Prairie near Bethany	.285	.....
1799	Surface six inches	Prairie near Bethany	.290	.....
1801	Surface six inches	Prairie near Bethany	.241	.....
1798	Surface six inches	Adjacent cultivated field	.196	.....
1800	Surface six inches	Adjacent cultivated field	.210	.....
FIELDS ON EXPERIMENT STATION FARM.				
1817	Surface six inches	Cornfield, plowed portion	.257	89
1818	Surface six inches	Cornfield, plowed portion	.271	90
1819	Surface six inches	Cornfield, plowed portion	.274	91
1820	Surface six inches	Cornfield, unplowed portion	.256	124
1821	Surface six inches	Cornfield, unplowed portion	.245	121
1822	Surface six inches	Cornfield, unplowed portion	.259	115
1823	Surface six inches	Cornfield, unplowed portion	.260	101
1824	Surface six inches	Cornfield, unplowed portion	.275	117
1825	Surface six inches	Cornfield, unplowed portion	.260	118
Average	Surface six inches	.....	.262	.....
1826	Surface six inches	Adjacent pasture	.284	132
1827	Surface six inches	Adjacent pasture	.262	139

TABLE 2.—*Nitrogen content of surface soils from near Lincoln—Concluded.*

Soil No.	Depth	Field	Nitrogen	Average weight of cores
	Inches		*Per cent*	*Grams*
FIELDS ON RESIDUAL SOIL FROM DAKOTA SANDSTONE.				
1735	Surface six inches	Prairie	.132	.....
1736	Surface six inches	Prairie	.133	.....
1737	Surface six inches	Cultivated field	.097	.....
1738	Surface six inches	Cultivated field	.097	.....
WHEAT FIELD NEAR BETHANY.				
1607	Surface six inches	From level hilltop	.199	.....
1606	Surface six inches	From steep slope	.104	.....
1608	Surface six inches	From foot of slope	.198	.....

IN THE SAND HILLS

From the crests of sand hills near Dunning, Blaine county, the samples of soil reported in Table 3 were taken. The barest hills were purposely selected in order that the samples might be representative of the Nebraska surface soils lowest in nitrogen and humus. A much higher percentage of nitrogen and humus occurs in the surface soil of the basins and valleys of these sand hills.

TABLE 3.—*Composition of soil samples from sand hills, near Dunning.*

Soil No.	Depth	Humus	Humus ash	Nitrogen
		Per cent	*Per cent*	*Per cent*
771	Surface six inches	...	...	.027
774	Surface six inches	.16	.53	.025
775	Surface six inches	.18	.14	.024
777	Surface six inches	.14	.09	.018
772	First foot	...	...	.028
773	Second foot	...	...	.013
778	First foot	...	...	.024
779	Second foot	...	...	.013
780	Third foot	...	...	.007
784	First foot	...	...	.021
785	Second foot	...	...	.021
790	First foot	...	...	.014
791	Second foot	...	...	.006
796	First foot	...	...	.013
797	Second foot	...	...	.011

ON THE HIGH PLAINS

IN CHASE COUNTY.—On the High Plains in western and northern Nebraska there occur various types of soil, some as coarse as

the dune sand reported in Table 3 and others as fine in texture as the soils from the western part of the loess area. These variations in texture are accompanied by corresponding variations in the nitrogen content, the finer the texture the higher being the nitrogen content of the surface soil of the virgin prairies.

The data on samples from near Imperial in Chase county, given in Table 4, illustrate the conditions on the western part of the High Plains in Nebraska. The surface soil of these two prairies a mile apart and both about three miles east of Imperial was sampled in inch sections. Ten cores were taken in one to a depth of 12 inches and ten in the other to a depth of 6 inches, and these subdivided. In the first prairie the soil was a very light sandy loam with a uniform, open, sandy subsoil to a depth of more than six feet, while the other was a very heavy loam with a heavy subsoil and with rock occurring at a depth of about three feet.

TABLE 4.—*Nitrogen in surface foot of prairies near Imperial.*

Depth	Sandy land	Hard land
Inches	*Per cent*	*Per cent*
1	.084	.162
2	.078	.128
3	.088	.140
4	.079	.125
5	.071	.104
6	.067	....
7	.062	....
8	.060	....
9	.054	....
10	.054	....
11	.057	....
12	.065	....
Average	.068	

Immediately adjoining the sandy prairie and having a similar soil and subsoil was a large field which had been continuously under cultivation without the application of manure or the growing of any leguminous crops for 25 years and which at the time,

September 6, 1907, bore a good crop of corn. The owner of the farm, as well as the neighboring old settlers, considered this field one of the most productive in the county and thought that it had shown little or no appreciable decline in yield since it was first plowed. As it had been in corn nearly every year, it is probable that any marked change would have been recognized. The nitrogen content of the surface six inches of the cornfield was .054 per cent compared with .077 per cent in the prairie, a loss of .023 per cent. That this was about the usual loss under similar conditions is shown by the data in Table 5, the samples there reported being taken on the same occasion from various fields near Imperial. In each case the prairie sampled was immediately adjacent to the cultivated field with which it is compared and had the same type of surface soil. The nitrogen content of the prairies varied by more than 50 per cent, those high in nitrogen being on "hard land" and those low in nitrogen on sandy land.

TABLE 5.—*Losses of soil nitrogen caused by cultivation on the High Plains, near Imperial.*

Field	Years in cultivation	Depth of sample	Nitrogen		
			In cultivated field	In adjacent prairie	Loss
		Inches	*Per cent*	*Per cent*	*Per cent*
A	21	Surface six inches	.085	.103	.018
A	21	Second six inches	.070	.110	.040
B	21	Surface six inches	.108	.143	.035
B	21	Second six inches	.070	.107	.037
C	21	Surface six inches	.067	.093	.026
D	21	Surface six inches	.054	.080	.026
E	20	Surface six inches	.117	.137	.020
F	21	Surface six inches	.078	.103	.025
G	12	Surface six inches	.074	.099	.025
H	10	Surface six inches	.093	.105	.012
H	10	Second six inches	.053	.074	.021

During the various dry years which have been experienced since the county was first settled the sandy soils have proved by far the more productive. This is due not to their chemical com-

position but to their openness of texture, permitting the rains to quickly penetrate so deeply into the subsoil that little water is lost by evaporation. This was well shown at the time the fields mentioned in Table 4 were sampled. Between August 1 and 25 only 1.02 inches of rain had fallen, while between August 26 and September 6 3.52 inches had fallen. The examination of the fields on September 6 showed that the prairies on "hard land" had been moistened to a depth of only about 18 inches, while the sandy prairie and the adjacent cornfield were moist to a depth of more than six feet. The following autumn, winter, and spring were unusually dry, the total precipitation at Imperial between September 6, 1908, and May 4, 1909, amounting to only 3.88 inches. It is probable that most of the moisture found in the surface 18 inches of the "hard land" early in September had evaporated before May but that a large proportion of that in the subsoil of the sandy prairie was carried over.

Some of the conditions on the more humid portion of the High Plains are illustrated by the data given in Table 6, on samples taken from a farm near the eastern edge of Holt county. The soil of the farm is a light sandy loam. On part of it corn had been grown continuously for about 25 years without the application of barnyard manure or the growing of leguminous crops. Most of the field still produced a fair crop of grain but on a number of small areas the corn had practically ceased to produce any ears. The stalks on these areas year after year made a weakly growth, becoming about half as tall as on the rest of the field, tasseled and put forth ears, but failed to form any appreciable quantity of seed. Samples Nos. 1724 and 1733 were taken as representative of the surface soil of the main portion of the field and samples 1723 and 1725 as representative of that of the unproductive portions. Samples Nos. 1723 and 1726 were taken to the same depth from an adjacent virgin prairie. Each six-inch sample analyzed was a composite of five individual samples and the foot samples were composites from two borings. The

percentages of nitrogen in the prairie, the productive, and the non-productive soils were approximately .160, .120, and .050, respectively.

TABLE 6.—*Nitrogen in soil of a farm near Page, Nebraska.*

Soil No.	Depth of sample	Fields	Nitrogen
			Per cent
1726	Surface six inches	Virgin prairie	.169
1734	Surface six inches	Virgin prairie	.159
1724	Surface six inches	Long cultivated, but still productive, soil	.117
1733	Surface six inches	Long cultivated, but still productive, soil	.112
1723	Surface six inches	Long cultivated, unproductive soil	.040
1725	Surface six inches	Long cultivated, unproductive soil	.063
1727	First foot	Virgin prairie	.132
1728	Second foot	Virgin prairie	.070
1729	Third foot	Virgin prairie	.034
1730	Fourth foot	Virgin prairie	.024
1731	Fifth foot	Virgin prairie	.023
1732	Sixth foot	Virgin prairie	.022

ON THE GLACIAL DRIFT

In October, 1908, a farm near Syracuse was visited which presented many soil problems. The most of it was brought under cultivation over 50 years ago, and until it was secured by Professor E. W. Hunt some 15 years ago it had been farmed in the most shiftless manner. The plowed land had been kept continuously under cultivation without manure and without the growing of leguminous crops. Most of the farm is hilly and from various parts of it so much of the surface soil had been washed off and blown off that some of the fields had been abandoned. Professor Hunt, by the use of barnyard manure, the growing of leguminous crops, and deep plowing, had made the farm as a whole productive but some small areas still failed to give satisfactory returns.

While in general on such a farm as this the nitrogen problem is the most important, there are so many other problems that in trying to remedy defects every unproductive area has to be considered separately. The data given below indicate how little information is furnished by the nitrogen determinations alone.

The nitrogen content of the surface soil and subsoil of the prairie is shown in Table 7. The first six-inch sample was taken from near the top and the other two from the foot of the hill.

Near this prairie was a cornfield on most of which was a fair crop but on one spot near the center the corn was a complete failure. On this small area crops had been a failure year after year. The stalks reached a height of only a foot and a half to three feet and formed little or no grain. Surrounding this small area were thrifty plants six to seven feet tall and well eared. The nitrogen content of the surface six inches of the unproductive spot, .145 per cent, was low but not low enough to explain the condition of the corn. An examination by the auger, however, showed that the soil at a depth of only from 8 to 14 inches passed into the underlying soft shale, and so gradually that it was difficult to decide where the soil ceased and the rock began. Toward the edges of the area as the soil became deeper the corn improved. This was a case where nothing except an examination with the soil auger was needed in order to solve the problem. No remedy can well be applied to such an unproductive spot and the best thing to be done with it is to seed it to a grass that is adapted to shallow, fine-textured soils.

In an adjacent clover field there were a number of comparatively unproductive spots on which the soil was lighter in color than on the remaining productive portion of the field. The nitrogen content of the former was .158 per cent and of the latter .175 per cent. An examination of the subsoil of the unproductive spots and of the intervening productive land showed no appreciable difference in the texture to a depth of three feet. The difference in the nitrogen content of the surface soil is more apt to be a result of the nonproductivity than to be the cause of it, as a luxuriant growth of red clover was found on various exposed areas of subsoil. The cause of the nonproductivity remains an unsolved problem.

In another clover field there were a few small circular patches

that were practically barren, neither clover nor weeds growing upon them. The nitrogen content of the surface six inches was found to be .153 per cent, while that of the soil taken at a distance of five feet, where there was a luxuriant growth of clover, was .190 per cent. The texture below the surface foot was similar to that under the clover. The surface six inches contained a little alkali, while the second six inches was heavily charged with it. The cause of the nonproductivity in this case was the presence of alkali.

In another field of clover there were a number of spots on which the clover had been making an unsatisfactory growth. The nitrogen content of the surface six inches of soil on these was .192 per cent, while that of the surrounding soil was .196 per cent. An examination to a depth of three feet by means of an auger failed to disclose the cause of the poor growth and no appreciable quantity of alkali was found. This also remains an unsolved problem.

Several sets of samples were taken from a hillside in a corn field on which the crop was very uneven. This part of the field had all received the same treatment, but three distinct conditions were plainly to be distinguished. On the very gentle slope near the top of the hill there was a good stand of plants and the stalks had made a fair growth, but a third of them were barren and the others bore very small ears. On the steepest part of the hillside, below the above, the stand was very thin but there were few barren stalks and the ears were larger. At the foot of the hill there was a good stand of large stalks and nearly every one bore a good-sized ear. To express the crop conditions quantitatively, a bushel of ears was gathered from each of the three areas. The length of the rows from which they were gathered was measured and the number of stalks counted. From these data, assuming that one measured bushel of ears gives half a bushel of shelled corn, the estimates of yields given in Table 7 were made. Samples of soil from different depths--the first six inches, the second six

inches, the second foot, and the third foot—were taken from each of the three areas from which the corn had just been gathered. The soil in the first two areas was very compact, while that in the third was mellow to a depth of two feet or more.

TABLE 7.—*Nitrogen content of soil on farm of Professor E. W. Hunt, near Syracuse, Nebraska.*

Depth	No. of individual samples used in composite	Cornfield					Prairie
		Thin stand	Few ears	Good crop	12 ft. from fence	On grassy terrace	
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Surface six inches, sample No. 1	10	.181	.203	.208	.....	.....	.228
Surface six inches, sample No. 2	10	.193	.215	.198	.....	.....	.242
Surface six inches, sample No. 3	10	.....	.201	.....	.....	.....	.226
Average	10	.187	.206	.203	.....	.....	.232
Second six inches	5	.084	.099	.101	.....	.....	.161
First foot	5	.135	.153	.152	.175	.238	.204
Second foot	3	.064	.065	.093	.174	.152	086
Third foot	3	.038	.053	.063	.136	.....	.056
No. of plants per acre	.....	1476	5577	5830	.....	.....	.....
No. of ears per acre	.....	1352	3900	5724	.....	.....	.....
Bushels per acre	.....	9	20	53	.....	.....	.....

The nitrogen content was somewhat the lowest in the area with the thinnest stand, but in the surface soil there was practically no difference between the area giving a yield of 20 bushels per acre and that giving 53 bushels. The subsoil of the latter was richer in nitrogen, this being due to the accumulation of surface soil washed from the hillside. That much of the surface soil from the hillside had been washed down and deposited at the foot of the slope is shown in the figure in which may be seen a terrace at the edge of the cornfield. This had been gradually built up above the original surface. The formation of the terrace within and above the fence, instead of below it, is to be attributed to the unplowed strip within the fence, covered with

long grass and weeds, arresting the soil washed down from the slope. After each fresh deposit the vegetation would grow thru and upon it, thus firmly anchoring the new material in place and forming a barrier to arrest the material brought down by the next heavy rain. Samples were taken on both this grassy terrace, at a distance of three feet from the fence, and from the cornfield at a distance of twelve feet. In the case of the latter the soil was black and mellow to a depth of thirty inches.

A terrace formed at the foot of a slope which had been in cultivation 50 years. The original level of the surface is shown by the grass at the left.

No alkali was found in the subsoil.

The comparatively unproductive areas suffered more from the compactness of their soil than from any lack of nitrogen. Deep plowing, by rendering the soil more open and thus checking the erosion and permitting more water to enter the subsoil, as well as facilitating the deeper penetration of plant roots, would evidently improve conditions. Very deep plowing, Professor Hunt informs us, has since greatly improved the conditions on this hillside.

Thus, on the slopes of this one hilly farm the unproductivity is found to be due in some places to lack of depth of soil, in others to the presence of alkali, in others to too great a compactness of the soil, and in still other places to causes not explained. In not one of these instances would the analysis of the surface soil have indicated the cause of the difficulty.

THE RELATIVE AMOUNTS OF NITROGEN, CARBON, AND HUMUS IN SOME NEBRASKA SOILS

By F. J. Alway and C. E. Vail

The black surface soil of the loess prairies of Nebraska differs from the yellow or gray subsoil chiefly in the proportion of organic matter and in the physical properties as affected by this organic matter. The total organic matter of soils, including all the material of vegetable and animal origin, may be roughly divided into two parts, each consisting of a mixture of many, but as yet, almost altogether unknown, compounds. The one part, designated as *humus*, is soluble in dilute alkalies and may, after preliminary treatment of the soil with dilute acid, be leached out with an ammonia solution, while the other part, the unhumified organic matter, remains undissolved. Each of these two parts of the organic matter in the soil contains an important part of the soil nitrogen and each exerts an important influence on the physical properties of the soil, but the influence of the humus appears to be much greater than that of the unhumified organic matter. Probably the most important chemical function that each serves is as a source of nitrogen for growing plants, but neither is necessary for normal plant growth, provided that available nitrogen is supplied, as in the form of nitrates or of ammonium salts. The relative availability of the nitrogen in the two forms is a much disputed question but it is universally recognized that both are at least ultimate sources of available nitrogen.

The methods of chemical analysis employed in the determination of these three constituents—nitrogen, humus, and unhumified organic matter—differ much in the time required for their performance and in the accuracy and the reliability of the results.

The nitrogen of soils is regularly determined by chemists by the Kjeldahl method, which is both accurate and rapid of execu

tion. Where duplicate determinations of nitrogen are made by this method by a moderately experienced analyst and these are concordant, the results are to be regarded as both accurate and reliable.

The methods for the determination of humus are, up to the present time, in an extremely unsatisfactory condition, as is illustrated by the fact that the method still recognized as "official"—that adopted by the Association of Official Agricultural Chemists of the United States—gives results which are, in general, from 30 to 100 per cent too high. An exhaustive study of the different methods that have been proposed for the determination of humus was recently made at this Station,[1] as a result of which it was concluded that the Mooers-Hampton modification of the "official" method, and a somewhat altered form of the Cameron-Breazeale modification of the "official" method, as well as the Hilgard method, give accurate and reliable results. A very recent bulletin published by the Hawaii Agricultural Experiment Station[2] deals with the same subject but reports the failure of its authors to confirm the conclusions arrived at in this laboratory.

The determination of the unhumified organic matter is in an equally unsatisfactory condition for the reason that this constituent is not determined directly but is estimated by deducting the percentage of humus found from that of the total organic matter. Hence, any error in the determination of either total organic matter or humus causes a corresponding error in the determination of the unhumified organic matter. The determination of organic matter has been made by methods based upon either one of two different principles. In the one the soil, dried at 100° C. or 110° C., is ignited until no further loss in weight occurs; then any carbonate which has been decomposed at the high temperature is reconverted by the addition of ammonium carbonate. The loss in weight thus found—the volatile matter—is considered as organic matter. The other methods involve the determination of

the organic carbon and the estimation of the organic matter from this on the assumption that the carbon constitutes a certain definite part, usually considered to be 58 per cent. For the determination of the organic carbon three different methods have been employed, viz., (1) ignition of the soil, mixed with copper oxide, in a current of oxygen, (2) the oxidation of the soil with chromic acid solution, and (3) the combustion of the soil with sodium peroxide. The first method, which has been the basis of the remarkable development of organic chemistry during the past eighty years, is one permitting of great accuracy but is very time-consuming. The amount of time it requires is the objection that has prevented its universal use and which has caused the easier and more expeditious chromic acid method to be more generally employed. The latter, however, as it has been used, gives too low results on account of the incomplete oxidation of the organic matter.[3] Hall[4] has recently proposed a modification in the chromic acid method by which the oxidation is made complete so that as reliable results are to be obtained as by combustion with copper oxide. The sodium peroxide method[5] is of recent introduction and has had, up to the present time, a comparatively restricted use in soil analysis. As an indication of the concordance of the results obtained by the first two methods, the data in Table 1 are given.

TABLE 1.—*Organic matter in soils as found by different methods.*

Soil No.	Volatile matter	C × 1.724
	Per cent	*Per cent*
516	11.26	8.08
518	9 12	5.79
521	8.42	4.72
525	7.40	3.52
529	6.81	0.74

Accordingly, in any attempt to estimate the relations existing between the nitrogen, the humus, and the unhumified organic matter, we actually determine the ratios between the nitrogen,

the humus, and the organic carbon. An error affecting the accuracy of the determination of one of the three will affect two of the ratios and if two of the determinations are erroneous all three ratios will be erroneous, unless it should happen that an error in the one determination should compensate for an error in another, and thus give the true ratios. In general, however, ratios based on the determination of humus by the "official" method or of carbon by the chromic acid method must be rejected.

We undertook the study, the results of which are presented in this article, to determine what constancy, if any, exists in the ratios of organic carbon to nitrogen, of organic carbon to humus, and of humus to nitrogen in samples of soil taken at different depths in the same field, from the same depth in different fields in the same locality, and from the same depth in fields of similar history but in different localities. The exhaustive study of the methods of humus determination referred to above had not been begun at the time that many of the determinations of humus were made and it was not completed until some time after the junior author* had left this Station. As a result, the humus determinations are not as accurate as they could now be made, in the light of our present knowledge. All the carbon determinations were made by the combustion method and are to be considered reliable. However, some of these may be inaccurate, as, in order to shorten the time required and so increase the number of samples analyzed, duplicate determinations were made on only about one-fifth of the samples. This seemed justifiable in a preliminary study for the reason that in the hands of a skilled analyst but few carbon determinations are inaccurate, and a better idea of the general composition of the soils would be obtained than by the analysis of a smaller number, making duplicates of each. There is always the possibility, however,

* Since September, 1909, Mr. Vail has been on the faculty of the Colorado Agricultural College.

that in any particular determination there may be a leak in the apparatus, giving, as a consequence, too low a result for the carbon, and, accordingly, too low a carbon-nitrogen and carbon-humus ratio.

For the reasons thus detailed we consider the nitrogen determinations accurate, the carbon determinations accurate except possibly in a few unidentified instances, and the humus determinations in general only *comparatively* accurate. In cases where the ratios seemed either very high or very low, new humus determinations were made in duplicate or a duplicate carbon determination was made, but with a considerable number of the soils these irregularities and some important sources of error in the method of humus determination were not detected until all the soil samples had been used or had been combined to form composites, thus preventing a repetition of the analyses. Thus, for instance, the whole of the series of determinations of humus in the inch sections from the upland grove in Lancaster county have been omitted.

METHODS OF ANALYSIS

The nitrogen was determined in duplicate by the Kjeldahl method. The concordance of the duplicates is shown in Table 2.

The humus was determined by the Hilgard method, the 4 per cent ammonia solution being applied continuously to the soils, previously freed of lime and magnesia, until the washings were colorless. This usually required from 10 to 14 hours, according to the soil. This, as later found, is not sufficient for the complete extraction of the humus, for which 4 to 5 days' further treatment is required in the case of most of such soils.[8] The additional amount obtained by such continued treatment, however, is, in most cases, very small. A second source of possible error lies in the clay that is sometimes carried thru the filter in considerable quantities, with the result that too high a percentage of humus is found. Where the humus ash is determined, such an occurrence of clay in the humus extract is indicated by the

accompanying high percentage of humus ash. In the earlier determinations the humus ash was not recorded but in all the later determinations it was recorded and it is reported in the accompanying tables. The reason we report the percentage of this so-called "humus ash" is that it serves as an indication of the reliability of the humus determinations. A third source of error lies in the solubility, in ammonia solution, of the glass of the bottles in which the humus extract was stored previous to the completion of the determination. As the first part of the analysis—that involving the removal of lime and magnesia, subsequent washing with distilled water, and the extraction with ammonia—could be made most economically where a large number of samples were being simultaneously extracted, we extracted from 50 to 100 samples at a time and stored the extracts in glass bottles until the solutions could be evaporated. As platinum dishes are necessary for this evaporation, only a few determinations could be made in one day. At times the platinum dishes had to be used for other analyses, increasing still further the time that the extracts were stored in the bottles before the analysis was finished. The bottles used, as was later found, were all unusually readily soluble in ammonia. The result was that on evaporation the compounds formed by the solution of the glass in ammonia remained behind and when ignited lost weight, like the clay referred to above. In Table 3 are given the data obtained with freshly prepared extracts and with those which had stood in the bottles for two months.

TABLE 2.—*Concordance of duplicate determinations.*

Soil No.	Nitrogen		Carbon		Humus	
	1	2	1	2	1	2
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
538	.189	.189	2.04	2.06	2.12	2.15
539	.192	.185	2.04	2.11	2.20	2.30
540	.161	.164	1.67	1.54	1.90	1.80
541	.189	.189	1.91	....	1.85	2.00
542	.193	.186	2.01	1.96	2.10	2.05
543	.186	.186	2.01	2.10	2.06	2.27
544	.200	.194	2.07	2.04	2.00	2.00
545	.198	.194	2.14	2.13	1.83	2.20

TABLE 3.—*Effect of storing humus extract in glass bottles.*

Soil No.	Fresh extract		Extract stored		Difference	
	Humus	Humus ash	Humus	Humus ash	Humus	Humus ash
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
731	2.61	1.39	3.08	2.64	.47	1.25
732	3.17	1.07	3.50	2.54	.33	1.47
733	2.35	.99	3.08	2.70	.73	1.71
734	1.65	1.02	2.10	2.42	.45	1.40
735	2.99	.99	3.44	2.20	.45	1.21
736	2.47	.62	3.21	2.28	.73	1.66
737	1.73	.43	2.28	2.15	.55	1.72
738	1.91	.61	2.59	2.31	.68	1.70
739	1.99	.91	2.43	2.52	.44	1.61
740	1.42	.65	2.00	2.04	.58	1.39

Where the percentage of ash had been recorded, the presence of dissolved glass was indicated by the high humus ash content. New determinations were made in the case of all those samples where it exceeded 1.50 per cent. It is probable that among the analyses the results of which have been retained there are errors from this source. While a considerable number of the humus determinations may be inaccurate, it is evident from the following instance that most of them should be considered reliable. In the case of a series of fourteen individual samples from Custer county, determinations of both humus and nitrogen were made. The results are given in Table 4. Later the remaining portions of these samples, which were all of about the same weight, were

combined to form a composite which was used in the detailed study of the methods of humus determination already referred to. This soil is reported in Bulletin 115 as soil No. 2.[7] The humus in this as determined by the different reliable methods averaged 1.63 per cent, being 1.64 per cent by the Hilgard, 1.62 by the Cameron-Breazeale, and 1.63 by the Mooers-Hampton, while the average of the humus determinations on the individual samples was 1.62. The nitrogen content of the composite was 0.205 per cent.

TABLE 4.—*Composition of individual samples from a virgin prairie in Custer county.*

Sample No.	Humus	Humus ash	Total nitrogen	Humus / N ratio
	Per cent	*Per cent*	*Per cent*	
1	1.57	.36	0.186	8.4
2	1.77	.50	0.228	7 8
3	1.58	.35	0.214	7.4
4	1.80	.41	0.227	8.0
5	1 49	.27	0.200	7.5
6	1.48	.39	0.193	7.7
7	1.33	.29	0.197	6.7
8	1.67	.31	0.205	8.1
9	2.00	.54	0.227	8.8
10	1.43	.29	0.202	7.1
11	1.68	.39	0.212	8 0
12	1.87	.43	0.235	8.0
13	1.44	.36	0.201	7.2
14	1.53	.66	0.202	7.6
Average.	1.62	.40	0.209	7.8

The carbon was determined by combustion in oxygen, the carbonates present having been previously decomposed by means of phosphoric acid. The concordance of duplicate determinations is shown in Table 2, which gives a consecutive series of analyses, no determinations being omitted.

THE SAMPLES ANALYZED

The samples reported in Table 5 were taken with two augers, the one of $1\frac{3}{4}$ inch and the other of 1 inch diameter. The larger auger was used to remove the first foot of soil, after which the

smaller was employed to obtain the sample of the second foot. The larger auger was next used to enlarge the hole to the bottom of the second foot. Then by means of the small auger the third foot sample was taken. This process was continued for the still lower portions of the soil. The different foot samples analyzed were composites from two or more borings.

Nos. 528 and 529 were from a part of the campus of the Nebraska Wesleyan University which previous to 1889 had been part of a large pasture and which since that date had been mowed annually for hay. Occasionally the grass had been burned off in the spring.

Nos. 935 to 940 were taken by Mr. Robert Ashby from a lawn near Genoa. The native grasses of the prairie had been replaced by blue-grass.

Nos. 1459 to 1461 were from the upland portion, and Nos. 1462 to 1467 from the lowland portion, of a pasture field on the Experiment Station Farm. On this the native grasses have been crowded out but the field has never been plowed. The lowland portion of it is inundated at times by the overflow of Dead Man's Run but the soil regularly deposited at such times is soon covered by the grass which is able to grow thru it. The black soil which has thus gradually been formed now extends to a depth of from three to five feet. The upland portion of the field is above the reach of high water.

The samples reported in Table 6 are composites of from 10 to 12 cores taken to a depth of one foot with a $1\frac{3}{8}$ inch brass tube. The cores were subdivided in the case of the first field into 10 and in the case of the other three fields into 12 parts. The first field, part of the Nebraska Wesleyan University campus, has been described above. Nos. 1491 to 1502 were from what is known as Peck's Grove, a few hundred yards south of the Experiment Station. Some 30 or 40 years ago cottonwood trees were planted in the prairie and since then the soil has been left undisturbed. A considerable amount of debris from leaves and branches had col

lected on the surface but this was removed before the samples were taken. Nos. 1469 to 1480 were from the lower portion of the same grove, this portion being flooded after torrential rains.

Nos. 1610 to 1621 are from a field on the farm of the Hon. George Coupland, near Elgin. Previous to 1878 this field was part of the unfenced prairie and since then has been used as pasture.

The samples reported in Table 7 are composites of six cores taken with a brass tube to a depth of 6 inches. All are from the Experiment Station Farm, two from the pasture field described above, one from the adjacent cottonwood grove, and nine from plots in the adjacent orchard. The plots in the orchard, as well as the adjacent field from which Nos. 546 and 547 were taken, are on the upland.

Table 8 gives the data on samples corresponding to those just described, but taken to a depth of one foot by means of an auger. Each sample was a composite from four borings.

The samples reported in Table 9 were from various fields near Elgin. They were taken by means of a brass tube to a depth of 6 inches and are composites of from six to ten cores. The prairies from which the first four samples were taken are not adjacent but are all within a radius of two miles.

Table 10 contains the data on samples taken from various parts of the state.

In all cases before taking a sample of surface soil the vegetation was cut off even with the surface, but all remaining organic matter, including the living roots, was dried and ground up with the soil for analysis.

TABLE 5.—*Samples from different depths of prairies.*

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
*	First foot..	.240	2.82	2.69	....	11.7	11.2	1.0
528	Second foot	.111	.86	1.00	.....	7.7	9.0	0.9
529	Third foot.	.066	.43	.45	.....	6.5	6.8	0.9
	NANCE COUNTY, NEAR GENOA—UPLAND.							
935	First foot.	.255	2.61	2.47	1.61	10.2	9.7	1.0
936	Second foot	.102	.85	1.00	.90	8.3	9.8	0.9
937	Third foot.	.056	.31	.40	.52	5.5	7.1	0.8
938	Fourth foot	.042	.24	.30	.64	5.7	7.1	0.8
939	Fifth foot.	.034	.17	.19	.33	5.0	5.6	0.9
940	Sixth foot.	027	.14	.16	.36	5.2	5.9	0.9
	LANCASTER COUNTY, EXPERIMENT STATION FARM—UPLAND.							
1459	First foot..	.242	2.65	2.90	.88	11.0	12.0	0.9
1460	Second foot	.149	1.59	1.47	1.40	10.7	9.9	1.1
1461	Third foot.	.069	.68	.62	.42	9.9	9.1	1.1
	LANCASTER COUNTY, EXPERIMENT STATION FARM—LOWLAND.							
1462	First foot..	.243	3.06	2.97	1.06	12.6	12.2	1.0
1463	Second foot	.191	2.39	2.36	.76	12.5	12.4	1.0
1464	Third foot.	.128	1.56	1.76	.80	12.2	13.8	0.9
1465	Fourth foot	.062	.62	.87	1.01	10.0	14.0	0.7
1466	Fifth foot..	.088	.64	.92	.34	7.3	10.5	0.7
1467	Sixth foot.	.073	.62	.68	.35	8.5	9.3	0.9

* Average of 516-525.

TABLE 6.—*Samples from different portions of the surface foot of prairies.*

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
LANCASTER COUNTY, NEAR LINCOLN—UPLAND.								
516	First tenth...	.347	4.69	4 20	.....	13.5	12.1	1.1
517	Second tenth.	.295	3 60	3.45	.....	12.2	11.7	1.0
518	Third tenth..	.269	3.36	2.97	.....	12.5	11.0	1.1
519	Fourth tenth.	.251	2.92	2.81	.....	11.6	11.2	1.1
520	Fifth tenth ..	234	2.78	2.85	.....	11.9	12.2	1.0
521	Sixth tenth ..	.224	2.74	2.55	.....	12.2	11.4	1.1
522	Seventh tenth	.197	2.31	2.22	.....	11.7	11.3	1.0
523	Eighth tenth.	.184	2.19	2.27	.....	11.9	12.3	1.0
524	Ninth tenth .	.177	2.06	2 20	.....	11 6	12.4	0.9
525	Tenth tenth..	.173	2.04	1.72	.....	11.8	9.9	1.2
LANCASTER COUNTY, LINCOLN—UPLAND—GROVE.								
1491	First inch....	.465	6.68	.....	.....	14.4	.....	.....
1492	Second inch..	.316	3.94	.....	.....	12.5	.....	.....
1493	Third inch...	.267	3.28	.....	.....	12 3	.....	.....
1494	Fourth inch .	.230	2.80	.....	.....	12.2	.....	.....
1495	Fifth inch ...	.230	2 59	.....	.....	11 3	.....	.....
1496	Sixth inch...	.209	2.29	.....	.....	11.0	.....	.....
1497	Seventh inch.	.192	2.01	.....	.....	10.5	.....	.....
1498	Eighth inch..	.194	1.84	.....	.....	9 5	.....	.....
1499	Ninth inch.	.185	1.80	.....	.....	9.7	.....	.....
1500	Tenth inch...	.184	1.63	.....	.....	8.9	.....	.....
1501	Eleventh inch	.163	1.54	.....	.....	9.4	.....	.....
1502	Twelfth inch.	.161	1.54	.....	.....	9.5	.....	.....
LANCASTER COUNTY, LINCOLN—LOWLAND—GROVE.								
1469	First inch....	.416	5.67	4.32	1.48	13.6	10.4	1.3
1470	Second inch..	.332	4.29	3.34	1.22	12.9	10.1	1.3
1471	Third inch...	.276	3.41	2.74	.50	12 4	9.9	1.2
1472	Fourth inch..	.235	2.92	2.45	.47	12.4	10.4	1.2
1473	Fifth inch...	.215	2.66	.....	.....	12.4	.....	.....
1474	Sixth inch...	.198	2.60	.....	.....	13.1	.....	.....
1475	Seventh inch.	.196	2.50	2.29	.58	12.7	11.7	1.1
1476	Eighth inch..	.190	2.33	2.25	.37	12.3	11.8	1.0
1477	Ninth inch...	.174	2.09	2.08	.24	12.0	11.9	1.0
1478	Tenth inch...	.167	1.92	1.82	.39	11.5	10.9	1.0
1479	Eleventh inch	.157	1.86	1.87	.33	11.9	11.9	1.0
1480	Twelfth inch.	.153	1.79	1.93	.32	11 7	12.6	0.9

TABLE 6.—*Samples from different portions of the surface foot of prairies—Concluded.*

ANTELOPE COUNTY, NEAR ELGIN—UPLAND.

Soil No.	Depth	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
1610	First inch....	.296	3.78	2.12	.60	12 8	7 2	1.8
1611	Second inch..	.263	3.26	2.16	.72	12.4	8.2	1.5
1612	Third inch...	.227	2.44	2.04	.44	10.7	9.0	1.2
1613	Fourth inch..	.205	2.41	1.68	.78	11.8	8 2	1.4
1614	Fifth inch....	.195	2.23	1.66	.68	11.4	8.5	1.3
1615	Sixth inch...	.192	2.05	1.64	.76	10.7	8.5	1.2
1616	Seventh inch.	.177	1.84	1.68	.58	10.4	9.5	1.1
1617	Eighth inch..	.161	1.69	1.64	.68	10.5	10.2	1.0
1618	Ninth inch...	.155	1.63	1.34	.68	10.5	8 6	1.2
1619	Tenth inch...	.149	1.41	1.28	.44	9.5	8.6	1.1
1620	Eleventh inch	.133	1 41	1.48	1.04	10.6	11.1	1.0
1621	Twelfth inch.	.128	1.27	1.00	.72	9 9	7 8	1.3

TABLE 7.—*Samples to a depth of six inches from different fields and plots on the Experiment Station Farm, Lincoln.*

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
	UNPLOWED LAND.							
534	Upland pasture...	.289	3.13	3.15	.....	10.8	10.9	1.0
535	Lowland pasture..	.297	3.74	3.67	.....	12.6	12.3	1.0
536	Lowland grove....	.293	3.52	3.40	.....	12.0	11.6	1.0
	UNDER CULTIVATION 30 TO 40 YEARS.							
537	Cultivated crops 5 years, clover 2 years.....	.200	2.14	2.10	.45	10.7	10.5	1.0
538	Cultivated crops 5 years, alfalfa 2 years.....	.189	2.05	2.05	.40	10.8	10.8	1.0
539	Cultivated crops 5 years, grasses 2 years.....	.188	2.07	2.25	.....	11.0	12.0	.9
540	Clean cultivation 7 years....	.162	1.69	1.85	.....	10.4	11.4	.9
541	Various cover crops 7 years...	.189	1.91	1.92	.48	10.1	10.2	1.0
542	Millet as cover crop 7 years....	.190	1.98	2.07	.30	10.4	10.9	.9
543	Oats 5 years, weeds as cover crop 2 years....	.186	2.05	2.16	.40	11.0	11.3	1.0
544	Cultivated crops 5 years, litter mulch 2 years..	.197	2.06	2.00	.40	10.4	10.1	1.0
545	Various cover crops 7 years...	.196	2.13	2.01	.48	10.9	10.3	1.0
546	Alfalfa 11 years, corn 1 year.....	.252	2.54	2.56	.50	10.1	10.2	1.0
547	Alfalfa 12 years..	.235	2.44	2.67	.49	10.4	11.4	.9

TABLE 8.—*Samples to a depth of one foot from different fields and plots on or near the Experiment Station Farm, Lincoln.*

UNPLOWED LAND.

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
901	Upland pasture...	.233	2.68	2.29	.38	11.5	9.8	1.2
902	Lowland pasture..	.244	3.03	2.68	.43	12.4	11.0	1.1
903	Lowland grove...	.244	2.61	2.40	.60	10.7	9.8	1.1
	UNDER CULTIVATION 30 TO 40 YEARS.							
904	Cultivated crop 5 years, clover 2 years.....	.167	1.58	1.63	.18	9.5	9.8	1.0
905	Cultivated crop 5 years, alfalfa 2 years.....	.162	1.45	1.65	.34	8.9	10.2	0.9
906	Cultivated crop 5 years, grasses 2 years..	.161	1.45	1.39	.12	9.0	8.6	1.0
907	Clean cultivation 7 years.....	.143	1.24	.99	.23	8.7	6.9	1.2
908	Various cover crops 7 years...	.175	1.53	1.32	.24	8.7	7.5	1.2
909	Millet as cover crop 2 years....	.159	1.51	1.23	.26	9.5	7.7	1.2
910	Oats 5 years, weeds as cover crop 2 years ...	.172	1.62	1.30	.28	9.4	7.6	1.2
911	Cultivated crop 5 years, litter mulch 2 years..	.175	1.65	1.24	.26	9.4	7.1	1.3
912	Various cover crops 7 years...	.187	1.85	1.89	.38	9.9	10.1	1.0
913	Alfalfa 11 years, corn 1 year.....	.210	2.13	1.77	.27	10.1	8.4	1.2
914	Alfalfa 12 years..	.214	2.07	1.85	.47	9.7	8.6	1.1
915	Alfalfa 1 year....	.193	.....	1.80	.35	.....	9.3	.....
916	Alfalfa 1 year....	.216	.....	1.91	.62	.....	8.8	.....
917	Alfalfa 1 year....	.210	.....	1.88	.41	.....	9.0	.....

TABLE 9.—*Samples to a depth of six inches from different fields on the farms of the Hon. George Coupland and his neighbors, near Elgin.*

Soil No.	Description of field or plot	Nitrogen	Carbon	Humus	Humus ash	Ratios		
						C / N	Humus / N	C / Humus
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
1622	Virgin prairie	.242	2.92	2.17	.47	12.1	9.0	1.3
1637	Virgin prairie	.214	2.40	1.65	.48	11.2	7.7	1.5
1645	Virgin prairie	.218	2.44	1.43	.64	11.2	6.6	1.7
1647	Virgin prairie	.162	1.75	1.24	.46	10.8	7.7	1.5
1649	Cereal crops 31 years	.234	2.51	1.58	.76	10.7	6.7	1.6
1652	Cereal crops 22 years, alfalfa 5 years	.194	2.10	.....	.....	10.8	.....	.....
1654	Cereal crops 22 years, alfalfa 5 years	.178	2.15	1.60	.20	12.0	9.0	1.3
1657	Cereal crops 19 years, alfalfa 12 years	.207	2.21	.....	.....	10.7	.....	.....
1632	Cereal crops 23 years, alfalfa 7 years	.197	1.96	1.64	.51	9.9	8.3	1.2
1634	Cereal crops 23 years, alfalfa 7 years	.166	1.70	1.36	.48	10.2	8.2	1.2
1635	Cereal crops 27 years	.171	1.78	1.40	.70	10.4	8.2	1.3
1636	Cereal crops 27 years	.163	1.67	1.38	.74	10.2	8.5	1.2
1641	Cereal crops 27 years	.160	1.78	1.46	.70	11.1	9.1	1.2
1642	Cereal crops 27 years	.155	1.56	1.36	.74	10.1	8.8	1.1
1643	Cereal crops 27 years	.154	1.61	1.52	.72	10.5	9.9	1.0
1644	Cereal crops 30 years	.172	1.79	1.50	.50	10.4	8.7	1.2
1646	Cereal crops 30 years	.162	1.60	1.24	.46	9.9	7.7	1.3
1648	Cereal crops 30 years	.145	1.42	1.04	.76	9.8	7.2	1.4
1650	Cereal crops 23 years, alfalfa 7 years	.165	1.68	1.24	.78	10.2	7.5	1.3
1651	Cereal crops 16 years, alfalfa 6 years	.152	1.60	1.25	.57	10.5	8.2	1.3
1653	Cereal crops 22 years, alfalfa 5 years	.168	1.82	1.42	.80	10.8	8.5	1.3
1656	Cereal crops 30 years	.177	1.86	1.52	.84	10.5	8.6	1.2

TABLE 10.—*Samples of surface soil from prairies in various parts of Nebraska.*

Soil No.	Depth	County	Nitrogen	Carbon	Humus	Humus ash	Ratios		
							C/N	Humus/N	C/Humus
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*			
1560	1-12 in..	Pawnee.	.237	3.01	2.77	.....	12.7	11.7	1.1
1561	1-12 in..	Pawnee.	.288	3.45	3.28	.....	12.0	11.4	1.0
1563	1-6 in ..	Pawnee.	.273	3.17	.....	.....	11.6	.....	.....
1539	1-6 in...	Thayer .	.247	3.04	.....	.....	12.3	.....	.....
1540	1-6 in...	Thayer .	.240	2.82	.....	.....	11.8	.....	.....
1557	1-6 in...	Custer..	.202	2.51	1.64	.67	12.4	8.1	1.5
1559	1-6 in...	Nance ..	.242	2.90	2.04	1.48	12.0	8.4	1.4
1415	1-6 in...	Frontier	.197	2.40	1.54	.32	12.2	7.8	1.6
1603	1-6 in...	Lincoln.	.175	2.06	1.45	.51	11.8	8.3	1.4
1958	1-6 in...	Perkins.	.169	1.89	1.28	.....	11.2	7.6	1.5
1959	1-6 in...	Perkins.	.132	1.48	.95	.....	11.2	7 2	1.6
1960	1 6 in...	Perkins.	.092	1.00	.74	.....	10.9	8.0	1.4

The percentages of nitrogen, carbon, and humus decrease from the surface downward. They are lower in the surface six inches and in the surface twelve inches of cultivated fields than in similar depths of the adjacent prairies.

The *carbon-nitrogen ratio* decreases thru the first three feet of the upland prairies, but in the case of the lowland field it remains constant until the black soil has been passed thru. When the different inch sections of the surface foot are compared it is seen that there is, in general, an irregular decrease from the surface downward, but only in the case of the series from the upland grove is this decrease rapid. In the case of the surface six inches or twelve inches of prairies the highest ratio found was 12.7 and the lowest 10.2. Even between the soils from the extreme eastern and the extreme western parts of the state no characteristic difference was found. In samples taken to a depth of six inches the ratio was, in general, lower in the case of the cultivated fields than in the adjacent prairies. With the samples taken to a depth of twelve inches the ratio was markedly lower in the cultivated fields.

With the samples from different foot sections the *humus-nitro-*

gen ratio was found to decrease from the surface downward except in the lowland fields. Within the surface foot there was no definite decrease from the first to the twelfth inch. In the case of the surface six inches the ratio is much higher in the samples from the eastern part of the state than in those from the western. Between the surface soil of long cultivated fields and that of adjacent prairies no distinct difference was shown except where more or less of the surface had been eroded as a result of cultivation.

The *carbon-humus ratio* in the case of the Lancaster county upland prairie is practically a constant but in the case of the lowland grove and of the Antelope county prairie there is a distinct decrease thru the first few inches. For the surface foot the ratio is distinctly higher for soils from the western part of the state than for those from the eastern. It appears, in general, to be slightly lower in the surface soil of cultivated fields than in that of adjacent prairies.

The ratios for the surface soil are so nearly constant that one can satisfactorily estimate the carbon content from a nitrogen determination, thus rendering a carbon determination unnecessary for practical purposes. The actual humus determination for soils from a part of the state from which similar soils have been analyzed may well be omitted and the per cent of humus estimated from the nitrogen content.

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VARIATION IN YIELD AND METHODS OF ARRANGING PLATS TO SECURE COMPARATIVE RESULTS

By E. G. Montgomery

There is at present a demand for information regarding methods of securing comparative yield records with the smallest possible error, especially in cases where a large number of comparative tests are to be made and suitable land for this purpose is limited. There has been a rapid development in plat experiment work to answer all manner of agricultural problems; also the development of selection work for the improvement of varieties has made it necessary in some cases to make comparative yield tests of hundreds of selections, where differences of only five or ten per cent in yield were expected.

Not only is a high degree of accuracy necessary in this work, but often the area of suitable land, where all can be tested under the same conditions, is limited.

The data in this paper were secured from a plat of land 77 feet by 88 feet, which was divided by imaginary lines into 224 permanent plats, 5.5 feet square. (Fig. 1.)

The land has been sown continuously to Turkey Red winter wheat for three years. The plat was of about average uniformity and fertility, the yield averaging about 25 bushels per acre.

Each small plat has been harvested separately and the yield of grain and the per cent of nitrogen determined. The detailed data for two years, 1909 and 1910, have been submitted for publication by the United States Department of Agriculture, but the last year's data, together with summaries for three years, are given here.

Figure 1 is a plat of the area for 1911, giving the yield of grain for each plat in grams, and the percentage of nitrogen. The average yield per block is 550.9 grams but the extreme range is 346 to 802 grams.

532 2.13	514 2.06	525 2.20	501 1.96	534 2.10	486 2.03	483 2.19	451 2.06	395 2.08	440 2.13	432 2.03	441 2.11	410 2.15	470 2.14	
612 2.16	510 2.05	460 2.06	530 2.00	538 2.09	471 1.98	439 2.17	446 2.14	424 2.13	430 1.96	424 1.97	405 2.01	436 1.98	472 2.04	
515 2.10	480 2.20	485 2.08	534 2.06	423 2.05	421 2.11	446 2.15	393 2.02	414 2.09	421 1.97	422 1.95	423 2.03	380 1.96	432 2.02	D
553 2.03	542 2.00	583 2.11	524 2.13	420 2.08	436 2.05	428 2.18	400 2.17	383 2.08	434 1.98	395 1.94	421 2.06	490 1.95	467 2.00	
575 2.12	532 2.06	550 2.09	548 2.05	480 2.04	432 2.00	420 2.04	452 2.01	460 1.97	449 1.92	474 2.11	443 2.02	484 1.94	494 2.10	
576 2.14	559 2.13	353 2.07	530 2.21	576 2.05	583 2.07	566 2.15	517 2.04	530 2.13	346 1.98	495 1.97	474 1.88	434 1.86	573 2.05	
548 2.06	513 2.09	533 2.05	517 2.14	503 2.04	580 2.04	514 2.03	632 2.25	740 1.86	641 1.97	506 2.04	495 2.02	560 1.99	575 1.95	C
550 2.01	463 2.18	550 2.08	540 2.11	497 2.00	424 2.18	519 1.95	606 2.14	756 2.44	656 2.00	584 2.10	623 1.93	599 2.00	695 1.94	
465 2.09	456 2.17	487 2.01	343 2.26	628 2.24	728 2.13	616 2.05	620 2.16	724 2.13	675 1.95	647 2.09	710 1.96	711 1.98	633 2.01	
545 2.00	577 1.97	583 1.99	515 2.06	515 2.27	535 2.23	467 2.21	577 2.26	581 2.15	648 2.21	707 2.22	738 2.11	717 2.11	621 2.28	
504 2.02	657 2.31	760 2.14	551 1.93	528 2.07	558 2.18	575 2.11	531 2.05	686 2.10	656 1.97	716 2.19	739 2.02	730 2.08	658 2.03	B
582 2.00	596 2.01	595 2.00	622 2.01	644 2.06	541 2.08	584 1.96	673 1.92	676 2.04	712 2.32	666 2.11	688 2.04	639 2.04	555 2.06	
668 2.08	662 1.98	613 2.07	693 2.10	666 2.20	643 2.03	570 2.02	674 2.16	661 2.00	742 2.12	802 2.21	634 2.22	634 2.06	634 2.07	
661 2.07	582 2.03	590 2.03	560 2.07	585 2.14	576 2.09	500 2.08	542 2.17	557 2.05	538 2.15	500 2.29	588 2.16	685 2.16	587 2.16	
730 2.18	650 2.05	650 2.08	586 2.22	533 1.97	617 2.04	561 2.15	496 2.27	527 2.23	637 2.18	385 2.11	585 2.09	625 1.99	637 2.06	A
575 1.99	495 2.04	502 2.08	584 2.16	716 2.26	725 2.10	563 2.11	477 2.14	513 2.14	649 2.03	547 2.06	488 2.06	512 1.93	426 2.00	

Legend — *Yield in grams.* / *Per cent nitrogen.*

Fig. 1.—Two hundred and twenty-four blocks 5.5 feet square, yield of grain in grams, and per cent of nitrogen in each block. Nebraska Experiment Station. 1911.

The plats may be grouped into larger and still larger plats, to note the effect on the variation in yield. Figure 2 shows the method of grouping these plats in larger plats of 4, 8, and 16 small blocks.

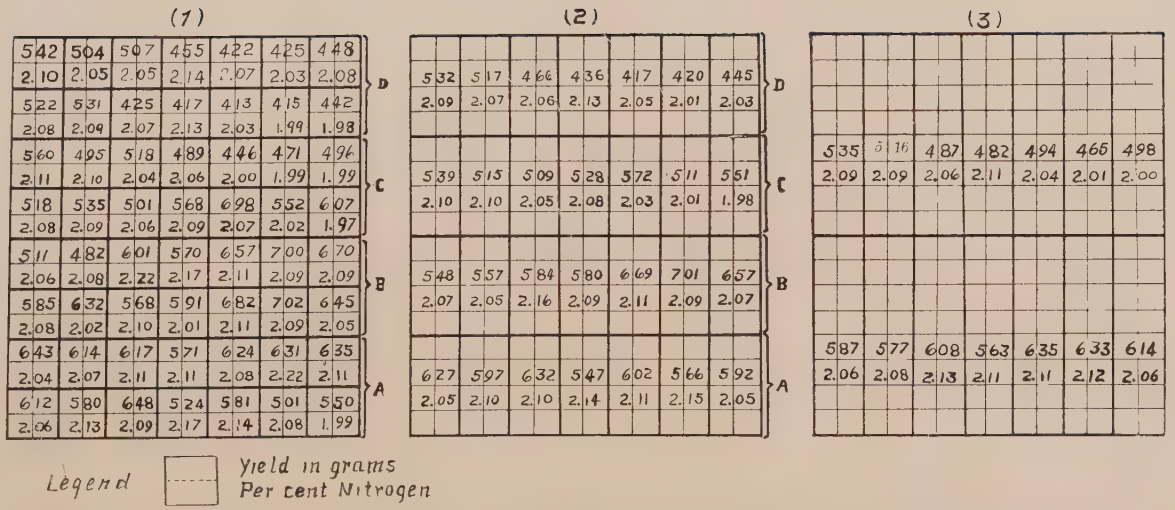

Fig. 2. This chart shows the plan of combining the plats into sets of 4, 8, and 16 adjacent plats.

For the purpose of comparing variation in the blocks of different sizes, it was desirable to have equal numbers of each size. The blocks were grouped in sets of 14, as indicated in figure 2 by A, B, C, D, giving four sets of the smallest size, two sets of the second size, and one set of the largest.

TABLE 1.—*Two hundred and twenty-four blocks of Turkey Red winter wheat arranged according to variation in yield, and in groups of 4, 8, and 16 adjacent plats. Nebraska Experiment Station. 1911.*

4 sets of 4 adjacent blocks in a group				2 sets of 8 adjacent blocks in a group		1 set of 16 adjacent blocks in a group	
Average yield	Deviation	Average yield	Deviation	Average yield	Deviation	Average yield	Deviation
A		C		AB			
Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
501.00	94.07	446.00	86.43	547.00	57 21	465.00	85.30
524.00	71.07	471.00	61.43	548.00	56 21	482.00	68.30
550 00	45.07	489.00	43.43	557 00	47.21	487.00	63.30
571.00	24.07	495 00	37.43	566.00	38.21	494.00	56.30
580.00	15 07	496.00	36.43	580.00	24.21	498.00	52.30
581.00	14.07	501.00	31.43	584.00	20.21	516 00	34.30
612.00	16.93	518.00	14.43	592.00	12.21	535.00	15.30
614.00	18.93	518.00	14.43	597.00	7.21	563.00	12.70
617.00	21.93	535.00	2.57	602.00	2.21	577 00	26.70
624.00	28.93	552.00	19.57	627.00	22.79	587.00	36.70
631.00	35.93	560 00	27.57	632.00	27.79	608.00	57.70
635.00	39 93	568 00	35 57	657.00	52.79	624.00	73.70
643.00	47 93	607.00	74.57	669.00	64.79	633 00	82 70
648.00	52 93	698 00	165 57	701.00	96.79	635.00	84.70
595.07	37.68	532.43	46.49	604.21	37 85	550 30	53.60
B		D		CD			
482.00	132.00	413.00	49.00	417.00	80.00		
511.00	103.00	415.00	47.00	420.00	77.00		
568.00	46 00	417.00	45.00	436.00	61.00		
570.00	44.00	422.00	40.00	445.00	52.00		
585.00	29.00	425.00	37.00	466.00	31.00		
591.00	23.00	425.00	37.00	509.00	12.00		
601.00	13.00	442.00	20.00	511.00	14.00		
632.00	18.00	448.00	14.00	515.00	18.00		
645.00	31.00	455.00	7.00	517.00	20.00		
657.00	43.00	504.00	42.00	528.00	31.00		
670.00	56.00	507.00	45.00	532 00	35.00		
682.00	68.00	522.00	60.00	539.00	42.00		
700.00	86.00	531.00	69.00	551.00	54.00		
702.00	88 00	542.00	80.00	572.00	75.00		
614.00	55.71	462.00	42.28	497.00	43.00		

TABLE 2.—*Summary of 224 blocks of winter wheat, each 5.5 feet square, to show effect on variation of combining in larger plats. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean yield per block	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
224 blocks 5.5 feet square		*Grams* 550.9	346.0 — 802.0	79.58	96.45	*Per cent* 17.50
4 adjacent blocks in a group	A 14	595.07	501.0 — 648.0	37.68	43.82	7.35
	B 14	614.00	482.0 — 702.0	55.71	65.44	10.65
	C 14	532.43	446.0 — 698.0	46.49	61.33	11.52
	D 14	462.00	413.0 — 542 0	42.28	46.42	10.00
Average		550.87	460.5 — 647.5	45.54	54.25	9.88
8 adjacent blocks in a group	AB 14	604.21	547.0 — 701.0	37.85	45.48	7.52
	CD 14	497.00	417.0 — 572.0	48.59	48.74	9.80
Average		550.60	482.0 — 636.5	43.22	47.11	8.66
16 adjacent blocks in a group	14	550.30	465.0 — 635.0	53.57	58.59	10.65

TABLE 3.—*Two hundred and twenty-four blocks of Turkey Red winter wheat, arranged according to variation in yield and in groups of 4, 8, and 16 plats not adjacent. Nebraska Experiment Station. 1911.*

Every 56th block, 4 blocks in a group				Every 28th block 8 blocks in a group		Every 14th block 16 blocks in a group	
Average yield	Deviation	Average yield	Deviation	Average yield	Deviation	Average yield	Deviation
Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
510.00	41.64	516.00	38.93	522.00	31.43	532.00	19.00
514.00	37.64	519.00	35.93	536.00	17.43	537.00	14.00
528.00	23.64	536.00	18.93	538.00	15.43	544.00	7.00
528.00	23.64	540.00	14.93	539.00	14 43	545.00	6.00
545.00	6.64	543.00	11.93	546.00	7.43	545.00	6.00
547 00	4.64	547.00	7.93	547.00	6.43	546.00	5.00
550.00	1.64	549.00	5.93	557.00	3.57	547.00	4.00
554.00	2.36	556.00	1.07	559.00	5.57	549.00	2.00
555.00	3.36	562.00	7.07	560.00	6.57	551.00	0.00
567.00	15.36	564.00	9.07	564.00	10.57	551.00	0.00
567.00	15.36	565.00	10.07	565.00	11.57	556.00	5 00
573.00	21.36	573.00	18.07	567.00	13.57	557.00	6.00
591.00	39.36	593.00	38.07	570 00	16.57	563.00	12.00
594.00	42.36	606.00	51.07	578.00	24.57	591.00	40.00
551.64	19.93	554.93	19.21	553.43	13.22	551.00	9.00
490.00	64.07	470.00	72.78	503.00	45.28		
508.00	46.07	493.00	49.78	526.00	22.28		
529.00	25.07	515.00	27.78	534.00	14.28		
535.00	19.07	516.00	26.78	537.00	11.28		
535.00	19.07	524.00	18.78	537.00	11.28		
539.00	15.07	538.00	4.78	542.00	6.28		
548.00	6.07	538.00	4.78	543.00	5.28		
549.00	5.07	544.00	1.22	547.00	1.28		
560.00	5.93	560.00	17.22	549.00	0.72		
569.00	14.93	563.00	20.22	554.00	5.72		
579.00	24.93	566.00	23 22	560.00	11.72		
601.00	46.93	570.00	27.22	561.00	12.72		
604.00	49.93	572.00	29.22	567.00	18.72		
611.00	56.93	630.00	87.22	616.00	67.72		
554.07	19.21	542.78	29.29	548.26	16.75		

TABLE 4.—*Summary of 224 blocks of winter wheat, showing result of repeating by systematic method on reducing variability. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean yield per block	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
		Grams				*Per cent*
224 blocks, 5.5 feet square		550.96	346.0 — 802.0	79.58	96.45	17.50
Every 56th block, 4 blocks in a group	14	551.64	510.0 — 594.0	19.93	24.82	4.50
	14	554.07	490.0 — 611.0	28.51	34.53	6.23
	14	554.93	516.0 — 606.0	19.21	24.27	4.37
	14	542.78	470.0 — 630.0	29.29	37.89	6.98
Average		550.85	496.5 — 610.2	24.23	30.38	5.52
Every 28th block, 8 blocks in a group	14	553.43	522.0 — 578.0	13.22	15.18	2.74
	14	548.26	503.0 — 616.0	16.75	24.46	4.46
Average		550.84	512.5 — 597.0	14.98	19.82	3.60
Every 14th block, 16 blocks in a group	14	551.00	532.0 — 591.0	9.00	13.43	2.44

Table 1 is an arrangement of the plats in each set of 14, ranked according to yield. This plan was used in order to bring out more clearly the range of variation and the degree of variation from the mean.

Table 2 is a summary statement showing the degree of variation for the three sized blocks. The original small blocks had a coefficient of variability amounting to 17.5 per cent, which was reduced to 9.88 per cent when the plats were made four times as large. However, further increase in size did not reduce the variation. This is not quite in accord with previous years. (See Table 5.)

The same blocks may be combined into larger units by another means, namely, systematic repetition. Thus we may take every 56th block, as, for example, blocks 1, 57, 113, and 169, and combine the yield. In this manner the blocks have been grouped into sets of 4, 8, and 16, and the detailed data are arranged in Table 3. Table 4 is a summary, and shows a marked reduction in variability as a result of systematic duplication. The comparative results secured by the two methods of combination are more clearly seen in Table 5, which is a summary for 1911 and a combined summary for three years.

TABLE 5.—*Summary. Comparison of effect of increasing size of block, versus systematic repetition, on decreasing variation in yield. 1911.*

SEASON OF 1911.

Method of combining blocks	Coefficient of variability			
	Single blocks	Sets of 4	Sets of 8	Sets of 16
	Per cent	*Per cent*	*Per cent*	*Per cent*
Blocks adjacent	17.5	9.88	8.66	10.65
Systematic repetition ..	17.5	5.52	2.60	2.44
COMPARISON FOR THREE YEARS—1909, 1910, 1911.				
Blocks adjacent.....	14.66	8.95	8.16	7.85
Systematic repetition...	14.66	5.51	3.22	2.01

In this case increasing the size of plat above four adjacent blocks has had very little effect on reducing variation. It would appear therefore that for this particular piece of land there would be no object in having plats larger than this minimum size, which is eleven feet square. It does not follow that the same area would be found to be minimum size under other conditions.

However, systematic repetition has had a very marked effect on reducing variability. While it might appear that increasing the size of the plat should reduce the error more rapidly than it does from the standpoint of increasing the number of plants and including more local soil variations, yet an equal number of large plats reaches over into new territory and includes new causes for variation. On the other hand, systematic repetition if indefinitely increased will reduce variation to zero.

VARIABILITY IN NITROGEN CONTENT

A similar study was made regarding the variability in the per cent of nitrogen. Tables 6 to 10 inclusive give the data and are self-explanatory.

TABLE 6.—*Two hundred and twenty-four blocks of Turkey Red winter wheat arranged according to variation in nitrogen and in groups of 4, 8, and 16 adjacent blocks. Nebraska Experiment Station. 1911.*

4 sets of 4 adjacent blocks in a group				2 sets of 8 adjacent blocks in a group		1 set of 16 adjacent blocks in a group	
Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation	Average per cent nitrogen	Deviation
A		C		AB			
1.990	.1100	1.970	.0780	2.050	.0460	2.000	.0760
2.040	.0600	1.990	.0580	2.050	.0460	2.010	.0660
2.060	.0400	1.990	.0580	2.050	.0460	2.040	.0360
2.070	.0300	2.000	.0480	2.070	.0260	2.060	.0160
2.080	.0200	2.020	.0280	2.070	.0260	2.060	.0160
2.080	.0200	2.040	.0080	2.090	.0060	2.060	.0160
2.090	.0100	2.060	.0120	2.090	.0060	2.080	.0040
2.110	.0100	2.060	.0120	2.100	.0040	2.090	.0140
2.110	.0100	2.070	.0220	2.100	.0040	2.090	.0140
2.110	.0100	2.080	.0320	2.110	.0140	2.110	.0340
2.130	.0300	2.090	.0420	2.110	.0140	2.110	.0340
2.140	.0400	2.090	.0420	2.140	.0440	2.110	.0340
2.170	.0700	2.100	.0520	2.150	.0540	2.120	.0440
2.220	.1200	2.110	.0620	2.160	.0640	2.130	.0540
2.100	.0414	2.048	.0396	2.096	.2860	2.076	.0327
B		D		CD			
2.010	.0810	1.980	.0840	1.980	.0760		
2.020	.0710	1.990	.0740	2.010	.0460		
2.050	.0410	2.030	.0340	2.010	.0460		
2.060	.0310	2.030	.0340	2.030	.0260		
2.080	.0110	2.050	.0140	2.030	.0260		
2.080	.0110	2.050	.0140	2.050	.0060		
2.090	.0010	2.070	.0060	2.050	.0060		
2.090	.0010	2.070	.0060	2.060	.0040		
2.090	.0010	2.080	.0160	2.070	.0140		
2.100	.0090	2.080	.0160	2.080	.0240		
2.110	.0190	2.090	.0260	2.090	.0340		
2.110	.0190	2.100	.0360	2.100	.0440		
2.170	.0790	2.130	.0660	2.100	.0440		
2.220	.1290	2.140	.0760	2.130	.0740		
2.091	.0360	2.064	.0359	2.056	.0336		

TABLE 7.—*Summary of 224 blocks of winter wheat, each 5.5 feet square, to show effect of combining in larger plats on variability in nitrogen content. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean per cent nitrogen	Extreme variations	Average deviation	Standard deviation	Coefficient of variability
						Per cent
224 single blocks		2.077	1.86 — 2.44	.0724	.0915	4.40
4 adjacent blocks in a group	A 14	2.100	1.99 — 2.22	.0414	.0542	2.58
	B 14	2.091	2.01 — 2.22	.0360	.0522	2.49
	C 14	2.048	1.97 — 2.11	.0396	.0446	2.18
	D 14	2.064	1.98 — 2.14	.0359	.0447	2.17
Average		2.076	1.99 — 2.17	.0382	.04892	2.35
8 adjacent blocks in a group	AB 14	2.096	2.05 — 2.16	.0286	.0350	1.67
	CD 14	2.056	1.98 — 2.14	.0336	.0403	1.96
Average		2.076	2.01 — 2.14	.0311	.0376	1.81
16 adjacent blocks in a group	14	2.076	2.00 — 2.13	.0327	.0387	1.86

TABLE 8.—*Two hundred and twenty-four blocks Turkey Red winter wheat arranged according to variation in nitrogen content, and in groups of 4, 8, and 16 plats not adjacent. Nebraska Experiment Station.*

Every 56th block, 4 in a group				Every 28th block, 8 in a group		Every 14th block, 16 in a group	
Per cent nitrogen	Deviation	Per cent nitrogen	Deviation	Per cent nitrogen	Deviation	Per cent nitrogen	Deviation
2.000	.0670	2.000	.0890	2.020	.0600	2.040	.0370
2.010	.0570	2.010	.0790	2.020	.0600	2.040	.0370
2.020	.0470	2.010	.0790	2.050	.0300	2.060	.0170
2.040	.0270	2.020	.0690	2.060	.0200	2.060	.0170
2.060	.0070	2.040	.0490	2.060	.0200	2.070	.0070
2.060	.0070	2.080	.0090	2.070	.0100	2.070	.0070
2.070	.0030	2.090	.0010	2.080	.0000	2.080	.0030
2.080	.0130	2.110	.0210	2.080	.0000	2.080	.0030
2.080	.0130	2.120	.0310	2.090	.0100	2.090	.0130
2.090	.0230	2.120	.0310	2.100	.0200	2.090	.0130
2.100	.0330	2.130	.0410	2.110	.0300	2.090	.0130
2.100	.0330	2.140	.0510	2.120	.0400	2.100	.0230
2.110	.0430	2.140	.0510	2.130	.0500	2.100	.0230
2.120	.0530	2.230	.1410	2.130	.0500	2.110	.0330
2.067	.0304	2.089	.0530	2.080	.0286	2.077	.0176
1.980	.0760	2.010	.0810	2.020	.0530		
2.000	.0560	2.040	.0510	2.020	.0530		
2.010	.0460	2.040	.0510	2.060	.0130		
2.020	.0360	2.060	.0310	2.070	.0030		
2.030	.0260	2.070	.0210	2.070	0030		
2.050	.0060	2.080	.0110	2.070	.0030		
2.070	.0140	2.090	.0010	2.070	.0030		
2.070	.0140	2.090	.0010	2.070	.0030		
2.080	.0240	2.110	.0190	2.070	.0030		
2.080	.0240	2.110	.0190	2.080	.0070		
2.090	.0340	2.130	.0390	2.080	.0070		
2.090	.0340	2.130	.0390	2.110	.0370		
2.100	.0440	2.160	.0690	2.110	.0370		
2.110	.0540	2.160	.0690	2.120	.0470		
2.056	.0349	2.091	.0359	2.073	.0194		

TABLE 9.—*Summary of 224 blocks of winter wheat, showing effect of repeating by a systematic method on reducing variability. Nebraska Experiment Station. 1911.*

Number of plats in group		Mean per cent nitrogen	Extreme variation	Average deviation	Standard deviation	Coefficient of variability
224 blocks, 5.5 feet square		2.077	1.86 — 2.440	.0724	.0915	*Per cent* 4.400
Every 56th block, 4 blocks in a group	14	2.067	2.00 — 2.120	.0304	.0363	1.750
	14	2.056	1.98 — 2.110	.0349	.0394	1.910
	14	2.089	2.00 — 2.230	.0530	.0637	3.050
	14	2.091	2.01 — 2.160	.0359	.0433	2.070
Average		2.076	2.00 — 2.150	.0385	.0457	2.195
Every 28th block, 8 blocks in a group	14	2.080	2.02 — 2.130	.0286	.0348	1.670
	14	2.073	2.02 — 2.120	.0194	.0279	1.350
Average		2.076	2.02 — 2.125	.0240	.0313	1.510
Every 14 blocks, 16 blocks in a group	14	2.077	2.04 — 2.110	.0176	.0208	1.000

It is interesting to note that the coefficient of variability is not as great with the per cent of nitrogen as with the yield, being 4.79 per cent for the three-year average against 14.66 per cent.

Practically the same results were secured here as in the former case. Combining four adjacent blocks reduced variability to about one-half, but further increase in size had only small effect. However, systematic repetition gave constant decrease.

Table 10 is a summary for 1911 and also combined summary for 3 years, 1909-'10-'11.

TABLE 10.—*Summary. Comparison of increasing size of block. versus systematic repetition, on decreasing variation in per cent nitrogen. 1911.*

SEASON OF 1911.

Method of combining blocks	Coefficient of variability			
	Single blocks	Sets of 4	Sets of 8	Sets of 16
	Per cent	*Per cent*	*Per cent*	*Per cent*
Blocks adjacent.....	4.40	2.35	1.81	1.86
Systematic repetition...	4.40	2.19	1.51	1.00
COMPARISON FOR THREE YEARS—1909, 1910, 1911.				
Blocks adjacent.....	4.79	2.42	2.08	2.09
Systematic selection....	4.79	2.28	1.49	1.09

VARIATION ON THE SAME PLATS FROM YEAR TO YEAR

It was noticeable from the first that certain areas of the large plat averaged distinctly higher than the average, while other areas were low. Figure 3 is a chart showing the location of the high and low areas for three successive years. The high area shifted in the three years from the northwest quarter to the east side. In fact, a portion of the very area which was high in 1909 was low in 1910. The cause of this shift is not clear. There were seasonal changes, and certain of these areas may have been better suited than others to the requirements of different seasons. Also, as the land was continually in wheat for three years it is possible that one portion was better able to produce under continuous wheat cropping. Whatever the cause or causes of this shift in high and low yield, it illustrates the difficulty in standardizing the yield of plats.

In conclusion, there is a wide degree of variation in the yield and in the per cent of nitrogen in small wheat plats. This is true of adjacent plats, and also there is a tendency for the high and low yielding plats to be localized in certain definite areas. The high areas, however, are likely to shift from year to year.

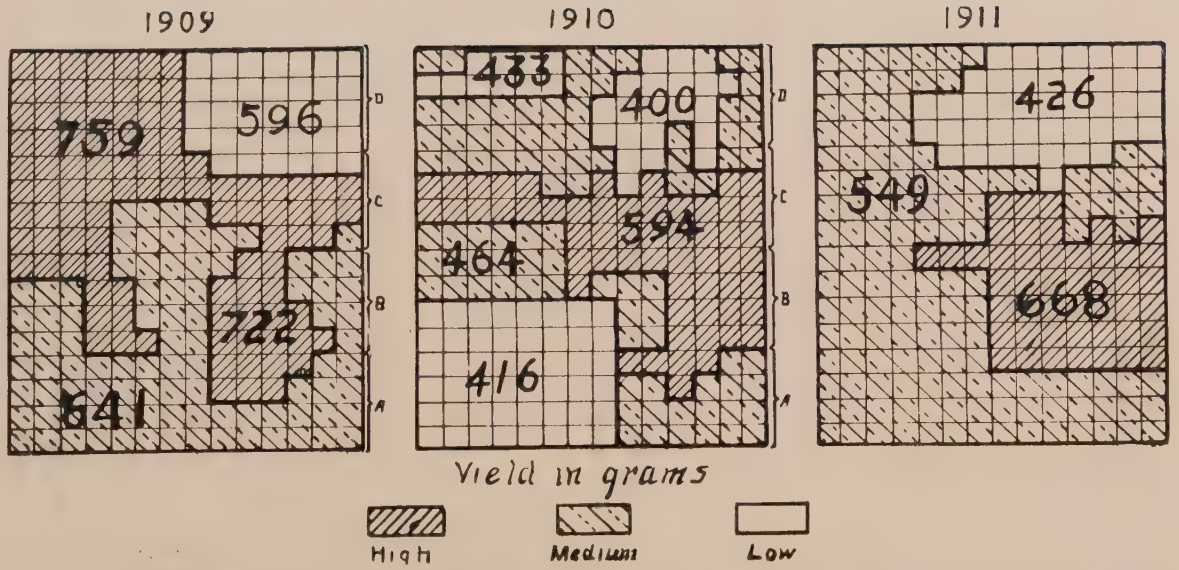

Fig. 3. Chart showing the "high" areas and "low" areas in yield of grain for three years, 1909-1911. The high area tended to shift toward the southeast part of the plat. The figures indicate average yield in grams per plat.

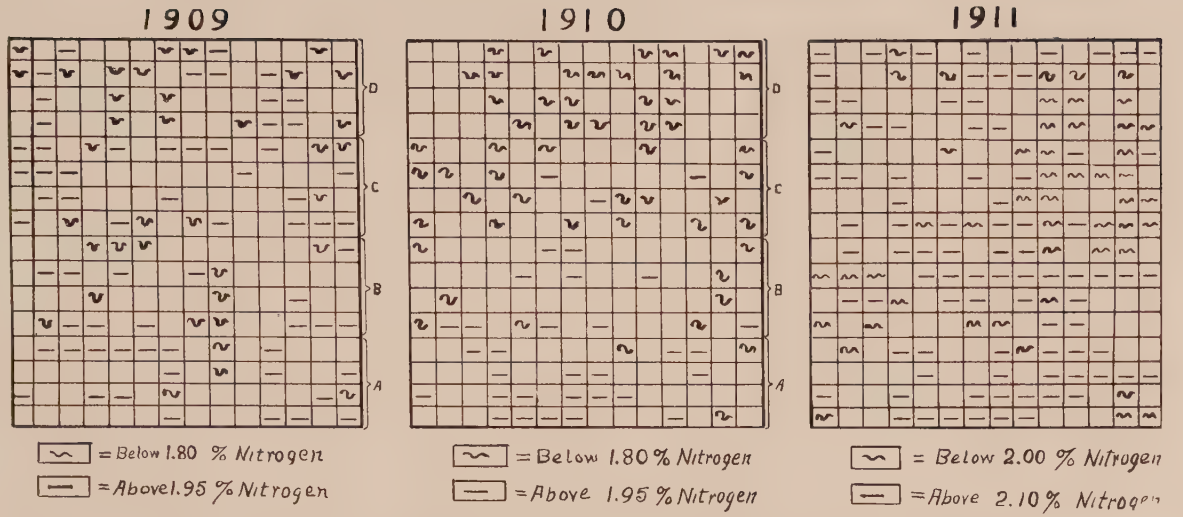

Fig. 4. Showing location of plats high or low in average nitrogen content. The variation in nitrogen in the plats is not great (see Tables 7, 8, and 9). There is some tendency for the plats producing high nitrogen wheat and low nitrogen wheat to localize, but this tendency apparently bears no relation to variation in yield.

Increasing the size of the plat has only a slight effect on decreasing the variability after a certain minimum size is reached.

The only method of securing comparative yield tests that will meet all of the fluctuating variations is systematic repetition.

With sufficient repetition very small plats may be used and thus a large number of comparative tests made on a rather small area of ground.

We have found a block 5.5 by 16 feet to be a very convenient size. This makes three plats to the square rod or 480 plats per acre. Forty-eight comparative tests per acre can be made, repeating each 10 times, with a much higher degree of accuracy than when tenth-acre plats are repeated twice or three times.

PRELIMINARY REPORT ON EFFECT OF CLOSE AND BROAD BREEDING ON PRODUCTIVENESS IN MAIZE

By E. G. Montgomery

It has been known for many years that self-fertilization has an injurious effect on the yield of corn, and on the other hand it has been observed that broad breeding or the cross of two unrelated strains has often been quite beneficial. It is possible to conceive of several degrees of relationship between self-fertilization on one hand and the crossing of two unrelated varieties on the other. The object of this experiment was to determine, if possible, the degree of relationship where close fertilization ceased to be injurious and where crossing became beneficial. The problem came up in connection with the question of handling certain high-yielding strains, which had been secured in the ear-to row breeding work. The question was, whether it would be advisable to use a single high-yielding ear as a foundation stock or to cross together a number of desirable ears in order to maintain yield. If a single desirable ear could be safely used as a foundation stock and the yield indefinitely maintained, it would simplify our work in the improvement of corn.

In 1907 a series of ear-to-row breeding plats were put out at the Experiment Station. The progeny of four of the best-yielding rows was used as a basis for the degree-of-relationship experiments here described. Five ears were selected from the progeny of these four original ears, and a part of each ear was planted in an isolation plat. In a second plat a part of each ear was planted for close-breeding experiments and in the third plat a cross-fertilization experiment was started, using ears from other high-yielding strains of the same variety. It was proposed to test the following degrees of relationship:

No. 1. *Self-Fertilization.*—In this case the ear would each time be fertilized by pollen from the tassel in the same plant.

No. 2. *Close-Fertilization.*—Each ear would be fertilized by a mixture of pollen from 10 to 15 sister plants. Continued each year from a single ear.

No. 3. *Close-Fertilization.*—Each ear would be fertilized by a composite sample of pollen from fifteen sister plants, all from the same original ear. Stock continued from composite sample of 15 ears.

No. 4. *Cross-Fertilization.*—In this case each year a part of the plants from each strain will be detasseled to be fertilized by plants from one of the other three strains.

No. 5. *Ear-to-Row Breeding.*—Nos. 3 and 4 above had been taken from the best four strains of our old Class 1, which has been bred by the ear-to-row method since 1903. (See Nebr. Bul. No. 112, p. 5.)

No. 6. *Check Plats.*—This seed is secured each year from the original grower of the corn, Mr. R. Hogue of Crete, Nebr. He practices the customary method of selecting good ears from the field. It is not known whether the yielding power of the check is also changing.

The work has been continued for three years, 1909, 1910, and 1911. This report is necessarily preliminary and it is proposed here to give a report only on observations made so far.

The following yields were secured in 1911:

TABLE 1.—*Showing effect on yield, of five different methods of fertilizing corn for seed, based on relationship.*

Method	Description of method	Yield per acre in 1911
		Bushels
No. 1	Inbred for two years (1909-1910)	9.90
No. 2	Close bred for two years. Stock continued each year from a single ear	37.66
No. 3	Close bred for two years. Stock continued each year from a composite of 15 ears	41.30
No. 4	Natural cross breeding (4 strains intercrossed each year by detasseling)	43.89
No. 5	Ear-to-row selections	44.02
No. 6	Check. (Original corn grown under field conditions and best ears selected for seed)	40.70

COMMENTS ON RESULTS

INBREEDING.—(No. 1.) Figure 1 is a photograph illustrating the relative sizes of Nos. 1, 2, and 4. It is apparent here that the inbred corn has been much reduced in size and yield. Two inbred strains were practically sterile in 1910 and two more in 1911. Not all the inbred strains have been equally reduced, some being fairly productive, as indicated by the following estimate of yield for the strains in 1911:

TABLE 2.—*Yield of inbred strains of corn, 1911.*

Plat No.	Yield	Plat No.	Yield
	Bushels		*Bushels*
1	22.2	7	10.8
2	3.0	8	1.6
3	Sterile	9	8.5
4	4.2	10	18.1
5	23.2	11	7.3
6	Sterile	12	15.1

This reduction in yield and vigor has been noted by Shull[1] and East.[2] East also found that certain strains withstood inbreeding

[1] Shull, Geo. H. Vol. IV, p. 296 (1907); Vol. VI, pp. 63-72 (1909).

[2] East, E. M. Inheritance in Maize. Conn. Exp. Sta. Bul. 167 (1911).

with less reduction and yield than others. It is possible that strains may be found that withstand inbreeding indefinitely without becoming sterile.

Fig. 1. The effect of three degrees of relationship in crossing is here illustrated. Nos. 3 and 4 are pure strains from seed-stock inbred for three years; No. 2 from a close fertilized seed-stock, the plants each year being fertilized with pollen from sister plants, grown from the same ear. No. 1 is from seed stock that has been cross-fertilized for three years.

Each of the inbred strains (with one exception) appeared to be practically a pure type; i. e., all the plants from an inbred strain were practically alike in detail. The pure types secured were very different in appearance. Two types were practically free

from tillers, while others showed great capacity for tillering, developing two or three tillers as large as the primary plant. In one type all the stalks had a decided red color, and in another case the plants were very large, with a bend approximating one-fourth their height near the base. Figures 4, 5, 6, and 7 illustrate some of the types secured.

Fig. 2. The effect of inbreeding is here illustrated. Row 2 is from seed ear inbred for two years and is about one-half normal size. Row 1 is also from seed ear inbred two years but has not yet shown injurious effect. Row 3 is from a cross-bred seed ear.

Close Breeding.—(No. 2.) In this case pollen from sister plants has been used to fertilize each ear; but stock continued each year from a single ear. Eleven close bred strains were grown this year, and gave variable results, the yield ranging from 27.13 bushels to 58.18 bushels per acre, the average being 37.66 bushels. The plants were reduced in vigor. (See figure 1.) In time probably they would be as much reduced as the inbred

plants, as the chances are that the strains would be slowly brought to homozygous types.

The yield is already considerably reduced and will be further reduced in the future.

Fig. 3. Contrast in two pure types under field conditions. In row 4 all plants were sterile. In row 5 all plants were tall, coarse, with a long bend at the base.

Close Breeding.—(No. 3.) In this case a composite sample of pollen from 15 sister plants has been used to fertilize each ear, but stock continued each year from a composite of 15 ears. This was intended to illustrate a case where a single ear would

be isolated and used as foundation stock for building up a strain. It is possible, however, that results are not strictly typical, as the number of seed ears from which to select seed is necessarily limited. The principal difference, however, is that if there is a decrease in yield, under the conditions of the experiment, it would be shown in fewer years than under field conditions.

Results, however, show a different reaction in the three strains under test, the yields being 52.73, 34, and 38.38 bushels per acre respectively, the average being 41.7 bushels. Results indicate a small average decrease in yield to date, and also that, while certain ears might retain a high yield when planted and continued in an isolated plat, in other cases a decided decrease is to be expected.

Cross-bred Strains.—(No. 4.) The four strains of corn used for this are the same as in Nos. 3 and 5, and originated as described under the next head. The plan has been to plant each year two rows of each thru the center of a 12-row plat of one of the other strains, detasseling the two rows, and saving seed from these two detasseled rows. The experiment has been continued with the seed harvested in this way each year. After three years the intercrossing has been so general that the original strains have lost their identity, and from now on the experiment is practically a test of using seed from detasseled rows. Yields this year give only a slightly better yield than the original check.

Ear-to-Row Selections.—(No. 5.) These strains originated as the result of ear-to-row selections beginning in 1903 and continuing for four years (Bul. 112, p. 5). In 1907 the best strains were grown in increase plats, but in 1908 six ears were taken from each of four strains, and the ear-to-row selection has been continued since with these. Each year six ears are selected from the best of the six rows, from each strain. The number of rows is so few that the experiment should be rather a severe test of the question, "Can yield be maintained by continued ear-to-row breeding, or will there be injurious results from close breeding?"

Fig. 4. Homozygous type from Plat 10 (1911). The plants were very straight, and free from tillers.

Fig. 5. Homozygous type from Plat 7 (1911). Two to three strong tillers were produced from each plant.

Fig. 6. Homozygous type from Plat 5 (1911). Each plant very coarse and with a decided bend near the base.

Fig. 7. All plants came true to type. The plants were practically all sterile.

Last year and this, this seed was compared with check plats, with the following results:

TABLE 3.—*Ear-row-bred seed after seven and eight years continuous selection in comparison with "check" of original corn.*

Year	Ear-row stock yield per acre	Check stock yield per acre
	Bushels	*Bushels*
1910	56.6	54.4
1911	44.0	40.7

In this case, even with very narrow ear-row selection, the stock has so far maintained its yield. With a greater number of ears better results would be expected.

IMPROVED CORN UNDER FIELD CONDITIONS.—The question has frequently arisen as to whether a stock that had been improved by ear-to-row selection would maintain its yield under field conditions. The above stock, which was placed in increase plats in 1907, has been grown under field conditions since, and compared each year with a check. The custom has been to select only good ears for seed in the ordinary way.

TABLE 4.—*Comparison of ear-to-row bred seed and "check" grown under field conditions without further selection.*

Year	Seed originated by ear-to-row breeding (Class I)	Check	Difference
	Bushels	*Bushels*	*Bushels*
1907	82	72.5	9.5
1908	66	59.0	7.0
1909	..	....	..
1910	58	49.1	8.9
1911	54	51.0	3.0

A difference in yield is still maintained, tho not as marked this last year as heretofore.

Fig. 8. Method of covering ear and tassel for inbreeding.

CONCLUSIONS

Perhaps the most important result indicated so far by the investigation is that all degrees of close relationship are injurious and the yield is improved as relationship is widened. Apparently best results would not be secured from using a single ear as foundation stock, on the average, tho certain ears might give excellent results planted in this way.

Under natural conditions, however, there is no doubt a certain amount of self and close fertilization. This must be especially true in strains where the silk and pollen are produced at the same time. Every self or close fertilized grain is apt to produce a plant much reduced in yield or barren. This probably accounts for a certain per cent of the small or barren plants in cornfields. By sowing seed from detasseled rows, all the self-fertilizing and much of the close-fertilizing is prevented, and will result in increased yield.

It may also be added that the above results will probably vary considerably with different varieties, and should be verified under a variety of conditions.

EVAPORATION FROM A FREE WATER SURFACE AT LINCOLN, NEBRASKA*

By G. A. Loveland and S. W. Perin

The unusually dry season of 1894 directed attention to the need of a knowledge of evaporation in Nebraska and to the fact that no data were available for use. In the spring of 1895 equipment for measuring evaporation was installed on the farm of the Experiment Station near Lincoln, Nebr. A record of evaporation has been kept for the summer months to the end of the season of 1910. A summary of the records by months for the sixteen years is given in the table below. The rainfall and temperature recorded in the immediate vicinity of the pan and the wind velocity recorded on the University campus 2¼ miles distant, with the anemometer at an elevation of 82 feet, are included in the table, as they are factors affecting the evaporation so much as to be of interest in connection with amounts of evaporation.

The evaporating pan was constructed according to specifications of the United States Geological Survey. It is made of galvanized iron, 3 feet square and 10 inches deep. Around the top of the pan, on the outside, is riveted a strip of band iron. Four additional strips of band iron, riveted to the top piece, are then bent around under the pan, two strips in each direction, thus furnishing the necessary stiffness. The pan is floated by two galvanized iron pontoons, 4 feet long and 9 inches in diameter and strengthened in the middle by braces. On opposite sides of the pan the band around the top projects a distance of 6 inches to form pairs of arms by means of which the pan rests on the pontoons. The device used for determining the amount of

* These records were kept by Mr. Perin and were reported monthly to Mr. Loveland, the Section Director.

evaporation consists of a series of inclined brass scales attached to a vertical frame, and the whole screwed to a light wooden cross-bar which rests upon the sides of the pan. These scales, which are intended only for differential measurements, are graduated downward from the top for every .05 of an inch of vertical height. Thus, a lower height of water has a higher reading on the scale.

As no body of water well located for the exposure of the pan was accessible, a reservoir, 10 feet square by $2\frac{1}{2}$ feet deep, was made, kept full of water, and the pan floated on its surface. Measurements were made once a day, in the evening about sunset. The pan was filled with water several times a month but not daily. The amount of water the pan collected during a rain was determined by a careful measurement in a rain-gage, and allowance made for this water in determining the amount of evaporation. The location and appearance of the pan are shown in the accompanying illustration.

The evaporating pan in position.

The following tables represent the monthly evaporation from free water surface reckoned in inches. They also embody the ecipitation by months as well as the mean monthly tempera-re and wind velocity:

Year	MARCH				APRIL			
	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
95	....	.....	.....	.....	.....	.....	.....	.....
96	.....	.....	.....	.....	5.03	3.99	57.8	15.2
97	.....	.....	.....	.....	3.57	5.08	51.1	14.7
98	.....	.....	.....	.....	5.43	2.83	50.7	13.6
99	.....	.....	.....	.....	.....	1.51	51.4	12.8
00	.....	.....	.....	.....	*2.42	4.70	54.8	12.1
01	.....	.....	.....	.....	4.44	1.63	51.8	12.6
02	.....	.....	.....	.....	4.79	0.76	52.1	12.7
03	4.29	0.57	40.0	11.5	4.20	3.41	53.2	15.2
04	.....	.....	.....	.....	4.67	5.13	46.0	15.6
05	.....	.....	.....	.....	5.32	3.55	50.2	11.4
06	.....	.....	.....	.....	4.81	2.86	56.0	13.1
07	.....	.....	.....	.....	4.26	0.77	44.0	13.2
08	.....	.....	.....	.....	5.89	1.93	53.7	13.6
09	.....	.....	.....	.....	4.68	1.34	48.0	14.3
10	.....	.....	.....	.....	6.72	0.05	56.2	15.4
Mean	.....	....	.. ...	.....	†4.71	2 63	51.8	13.7
Av. daily	.....	.....	.....	.....	0.16	0.09	.....	.....

Year	MAY				JUNE			
	Evap.	Precip.	Temp.	Wind Vel.	Evap.	Precip.	Temp.	Wind Vel.
95	6.54	1.05	64.4	8.2	5.04	5.08	70.6	9.6
96	5.28	9.76	63.5	13.0	7.06	2.88	69.6	9.2
97	5.80	1.94	61.3	10.2	5.61	2.01	73.0	10.8
98	4.09	5.29	60.4	10.9	6.79	4.91	73.5	9.8
99	5.33	2.32	63.4	12.2	5.94	8.24	72.0	11.0
00	5.81	3.38	64.9	9.5	6.59	3.55	72.1	9.7
01	5.50	2.10	62.0	10.6	7.09	1.59	75.9	12.1
02	5.19	3.50	66.5	11.9	6.01	8.60	68.0	10.4
03	6.79	11.13	61.6	12.9	5.54	2.49	66.0	8.2
04	5.60	4.32	62.0	10.4	5.24	3.69	68.6	8.7
05	7.00	4.72	60.7	13.0	7.79	3.59	72.7	11.3
06	6.55	1.71	63.2	12.8	7.74	3.46	70.0	10.7
07	6.53	3.66	57.2	13.0	6.38	6.59	69.4	10.3
08	6.11	5.26	59.7	11.8	7.89	11.73	69.0	12.0
09	5.91	4.60	60.6	11.5	6.68	1.95	70.7	8.6
10	5.58	3.30	57.0	10.8	7.77	1.64	71.6	9.6
Mean	5.85	4.25	61.8	11.4	6.57	4.50	70 8	10.1
Av. daily	0:19	0.14	.....	... .	0.22	0.15	....	.. . ..

* For 10 days. † April, 1900, not included.

Year	JULY Evap.	Precip.	Temp.	Wind Vel.	AUGUST Evap.	Precip.	Temp.	Wind Vel.
1895	6.76	0.91	74.8	8.5	6.07	3.86	75.0	9.6
1896	7.14	4.29	74.4	8.4	5.89	3.18	69.0	9.3
1897	8.32	3.44	78.2	10.6	6.35	1.85	74.8	8.6
1898	.....	6.60	74.7	9.6	7.40	2.82	75.2	9.0
1899	6.75	1.94	74.4	7.5	7.29	2.34	77.4	10.0
1900	9.09	6.68	76.2	11.6	7.07	7.96	78.7	11.7
1901	13.33	2.91	85.4	10.0	6.61	0.91	76.8	7.8
1902	7.65	11.52	75.0	10.0	4.40	4.30	73.2	8.6
1903	7.83	2.48	76.0	9.8	6.02	5.98	71.3	8.4
1904	6.23	5.03	73.0	8.9	6.08	2.48	72.6	8.2
1905	7.22	2.82	72.6	8.6	7.06	6.24	76.9	7.6
1906	5.89	7.88	71.9	7.4	5.77	2.32	74.9	8.6
1907	6.94	3.26	76.4	8.7	6.21	4.40	74.4	8.9
1908	7.02	9.58	73.8	8.4	5.58	2.30	73.2	8.4
1909	6.01	3.82	75.8	7.9	8.74	1.09	79.5	9.2
1910	7.39	2.42	76.6	8.0	5.63	14.41	73.6	8.6
Mean	7.57	4.72	75.6	9.0	6.39	4.15	74.8	8.9
Av. daily	0.24	0.15	.....	.....	0.21	0.14	....	....

Year	SEPTEMBER Evap.	Precip.	Temp.	Wind Vel.	OCTOBER Evap.	Precip.	Temp.	Wind Vel.
1895	5.23	0.63	74.2	13.9	.....	.....	.....	.....
1896	4.09	4.90	61.9	8.7	3.15	3.06	49.8	9.7
1897	5.97	1.92	74.6	9.9	3.14	2.62	59.9	11.2
1898	5.07	2.81	68.2	9.7	3.11	1.37	51.8	14.4
1899	6.02	0.62	66.9	10.6	3.92	2.51	59.8	11.4
1900	4.20	2.61	67.8	10.8	2.99	2.66	61.7	11.1
1901	4.95	6.36	66.4	10.7	2.92	3.20	57.0	10.0
1902	4.04	3.94	62.0	11.9	1.94	2.84	57.0	9.9
1903	4.83	1.39	63.6	12.1	4.27	2.96	55.5	10.6
1904	5.01	2.97	67.0	9.2	2.93	1.53	57.0	10.7
1905	4.19	7.69	63.3	9.5	3.48	2.69	51.8	10.3
1906	4.98	6.79	68.0	8.9	3.33	1.95	52.4	10.8
1907	5.23	3.40	66.2	9.8	3.51	1.15	53.7	9.7
1908	5.44	0.44	70.2	9.5	3.82	2.54	52.4	13.0
1909	4.68	4.48	66.6	8.0	3.76	0.47	53.2	11.1
1910	3.50	4.42	66.4	9.3	3.76	0.91	58.3	11.1
Mean	4.84	3.46	67.4	10.2	3.34	2.16	55.4	11.0
Av. daily	0.16	0.12	.....	.....	0.11	0.07	.....	.....

NOVEMBER

Year	Evap.	Precip.	Temp.	Wind Vel.
1895	*1.27	0.51	38.6	12.6
1896	.....	.....	.....	.....
1897	.....	.....	.....	.....
1898	....	.....	.....	.....
1899	1.52	0.61	46.8	9.0
1900	†0.65	0.07	37.8	9.6
1901	‡0.35	0.42	40.6	10.1
1902	.....	.....	.....	.....
1903	†1.28	1.80	38.9	11.5
1904	§0.55	0.18	44.5	8.3
1905	1.84	2.77	42.5	11.6
1906	‖0.67	0.32	38.6	9.9
1907	§0.93	1.08	39.8	10.0
1908	‖0.65	0.50	41.6	9.7

* For 19 days.
† For 14 days.
‡ For 7 days.
§ For 8 days.
‖ For 10 days.

EXPERIMENTS WITH TUBERCULIN

By J. H. Gain

The experience of some breeders who have bought cattle accompanied by a certificate of tuberculin test, especially cattle coming from without the state or the United States, has led them to believe that there are some methods used to nullify the tuberculin test. The most common belief is that the animal has been injected with tuberculin just prior to the official test. It has also been stated that by doubling the dose of tuberculin the influence of the previous dose can be overcome. The experiment here reported was undertaken to determine to what extent the tuberculin test might thus be nullified; also how long the influence of a normal dose of tuberculin would last and whether this influence could be overcome by increasing the dose.

In this experiment Government tuberculin was used.

Owing to the extreme drouth of the early summer this work was not continued as long as first intended.

At the conclusion of the experiment these cattle were shipped to South Omaha, where they were slaughtered under Government inspection and all found tuberculous. Of the ten head, seven were passed for food and three condemned as unfit for food and sent to the tank to be made into tankage and fertilizer; thus 70 per cent passed for food and 30 per cent were condemned. It might be stated here that these percentages as to disposition of carcasses are about the average for cattle that are found tuberculous upon post-mortem examination. Where herds have been given the tuberculin test and the reactors are sold subject to post-mortem inspection, the term "passed for food" does not mean that the animal was not tuberculous, but that the lesions of the disease were found in but a few places and small in size, and the meat therefore considered perfectly fit for food.

In this connection we quote from the Twenty-fifth Annual Report of the Bureau of Animal Industry:

"Under the inspection system the animals found tuberculous are disposed of in three classes, according to the extent of the disease. Carcasses which show very slight infection may often be safely passed for food after the removal of the lesions, the loss in such cases of course being small. Other carcasses, affected to a somewhat greater degree, but still not badly diseased, are allowed to be rendered into lard or tallow at a sterilizing temperature after all diseased portions have been cut away and condemned. In these cases the loss is more considerable. A third class comprises carcasses that are considered unfit for food in any form and are totally condemned. The loss on these is still greater, amounting in the case of cattle to about three-fourths of the cost. The salvage consists of the hide, grease, fertilizer, etc."

No. 1.—JERSEY COW.

August 29, 1910.			August 30, 1910				
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
102.4	102.0	101.8	103.2	104.4	104.2	101.4	100.8

Injected 9 P. M. August 29 with 2 c.c. tuberculin. High initial temperature accounted for by being led several miles on a warm day.

September 1, 1910				September 2, 1910				
8 A. M.	10 A. M.	12 M.	3 P. M.	8 A. M.	10 A. M	12 M.	2 P. M.	4 P. M.
100.0	101.2	101.4	101.2	102.0	101.6	101.6	101.6	100.8

Injected 9 P. M. September 1 with 5 c.c. tuberculin.

October 7, 1910			October 8, 1910					
12 M.	2 P. M.	5 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	5 P. M.
101.8	102.0	102.5	102.1	102.7	101.4	101.8	101.3	101.5

Injected 9 P. M. October 7 with 2 c.c. tuberculin.
Slaughtered and passed for food.

No. 1. The second test following the first with a two-day interval showed that two and a half times the initial dose of tuberculin failed to give a reaction. Five weeks later the ordinary dose of tuberculin gave no rise in temperature.

No. 2.—SHORTHORN COW.

August 26, 1910			August 27, 1910			
9 A. M.	12 M.	3 P. M.	6 A. M.	9 A. M	12 M.	3 P. M.
100.2	100.8	100.4	103.0	104.0	104.6	104.2

Injected 9 P. M. August 26 with 2 c.c. tuberculin.

September 2, 1910					September 3, 1910				
8 A. M.	10 A. M.	12 M	2 P. M.	4 P. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.
100.8	100.6	100.4	101.0	101.0	103.4	103.0	103.4	102.6	102.2

Injected 9 P. M. September 2 with 2 c.c. tuberculin.
Slaughtered September 17. Condemned.

No. 3.—SHORTHORN COW.

August 25, 1910			August 26, 1910			
9 A. M.	12 M.	3 P. M.	6 A. M.	9 A. M.	12 M.	3 P. M.
100.2	99.8	101.0	101.8	103.0	104.6	104 6

Injected 9 P. M. with 2 c.c. tuberculin.

September 2, 1910				September 3, 1910				
8 A. M.	10 A. M.	12 M.	2 P. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.
101.4	100.6	100.6	100.8	101.8	101 6	101.2	101.0	101.0

Injected 9 P. M. September 2 with 5 c.c. tuberculin.
Slaughtered September 17. Condemned.

In these tests of Nos. 2 and 3, both from the same herd, the injections were one week apart. No. 2, with a second injection

of 2 c.c., gave a sufficient rise in temperature to have been called a reaction, if in a badly infected herd, while No. 3, with a second injection of 5 c.c., did not show any disturbance.

No. 4.—SHORTHORN BULL.

Slaughtered June 29, 1911. Tuberculous. Passed for food.

August 25, 1910			August 26, 1910			
9 A. M.	12 M.	3 P. M.	6 A. M.	9 A. M.	12 M.	3 P. M.
102.0	101.4	101.4	104.4	105.8	107.0	106.0

Injected 9 P. M. August 25 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910					
3 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	3 P. M.	6 P. M.
101.5	102.0	103.7	104.8	104.7	105.2	104.2	104.0

Injected 9 P. M. October 7 with 2 c.c. tuberculin.

October 14, 1910			October 15, 1910					
9 A. M.	11 A. M	1 P. M.	7 A. M.	9 A. M.	11 A. M.	1 P. M.	3 P. M.	5 P. M.
102.3	101.3	101.0	102.0	101.3	101.4	101.4	102 0	102.0

Injected 9 P. M. October 14 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M	10:30 A. M	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.4	101.2	101.1	105.0	105.3	105.3	105.4	104 3

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M
103.0	102.3	102.3	104.2	104.4	104.2	105.1	104.1

Injected 8:30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 4 is from same herd as Nos. 2 and 3. The second test, six weeks after first, gave a typical reaction.

Seven months later a test with 2 c.c. of tuberculin gave a reaction. Immediately following this test an injection of 6 c.c. was given, which gave a positive reaction. The high initial temperature in the last test cannot be accounted for unless caused by the confinement.

No. 5.—ANGUS BULL.

Slaughtered June 29, 1911. Tuberculous. Unfit for food.

January 8, 1908		January 9, 1908		
2:30 P. M.	4 P. M.	8:30 A. M.	11 A. M.	2:30 P. M.
101.6	101.0	106.2	106.6	105.8

Injected 9 P. M. January 8 with 2 c.c. tuberculin.

December 23, 1908			December 24, 1908			
7 A. M.	10 A. M.	1 P. M.	7 A. M.	10 A. M.	1 P. M.	4 P. M.
101.0	101.0	101.6	104.8	105.0	105.8	104.6

Injected 9 P. M. December 23 with 2 c.c. tuberculin.

December 20, 1909			December 21, 1909			
8 A. M.	10:30 A. M.	1 P. M.	8 A. M.	10:30 A. M.	1 P. M.	2:30P.M.
101.0	101.4	100.4	100.3	104.8	104.0	103.4

Injected 9 P. M. December 20 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910					
3 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	3 P. M.	6 P. M.
101.4	102.5	102.0	102.4	103.0	104.2	103.9	103.5

Injected 9 P. M. October 7 with 3 c.c. tuberculin.

November 14, 1910			November 15, 1910					
8 A. M.	10 A. M.	12 M.	6 A. M	8 A. M.	10 A. M	12 M.	2 P. M.	5 P. M.
100.8	101.2	100.6	101.0	101 5	101.8	101.4	101.4	101.9

Injected 9 P. M. November 14 with 4 c.c. tuberculin.

May 17, 1911			May 18, 1911					
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.	6 P. M.
100.1	100.4	100.4	101.2	101.2	101.1	101.3	103.0	102.1

Injected 8:30 P. M. May 17 with 3 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M	1 P M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.0	103.0	103.0	103.2	105.2	104.4	104.4	103.0

Injected 8:30 P. M. May 19 with 8 c.c. tuberculin.
Slaughtered June 29, 1911. Condemned.

No. 5 was a bull weighing over a ton, of fine type, and during the whole period easily kept in good flesh. Found tubercular early in 1908, he gave each year a typical reaction until October, 1910, when the rise in temperature was less than 2 degrees. Thirty-seven days later with an injection of 4 c.c. of tuberculin his temperature remained normal. Six months later he gave a reaction that would not have been considered positive. The rise to 103 at 4:00 P. M. would not have been discovered in the

course of an ordinary test as the four previous temperatures would have been considered sufficient.

This case is interesting from the fact that there was evidently a considerable period when this animal would have passed a careful test as being perfectly free from tuberculosis.

The high initial temperature in the last test was probably caused by the confinement.

No. 6.—ANGUS STEER.

Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 20, 1909			December 21, 1909			
8 A. M.	10:30 A. M.	1 P. M.	8 A. M.	10:30 A. M.	1 P. M.	3:30 P. M.
102 0	101.4	101.4	104 6	106.4	106.8	106.0

Injected 9 P. M. December 20 with 2 c.c. tuberculin.

October 7, 1910		October 8, 1910				
3 P. M.	6 P. M	6 A. M.	8 A. M.	10 A. M	12 M.	3 P. M.
101.3	100.7	103.5	105.2	105.5	105.4	104.8

Injected 9 P. M. October 7 with 2 c.c. tuberculin.

October 9, 1910			October 10, 1910				
9 A. M.	11 A. M.	1 P. M.	7 A. M.	9 A. M.	11 A. M.	1 P. M.	3 P. M.
101.0	101 0	100.6	102.1	101.7	102.0	101.9	101.3

Injected 9 P. M. October 9 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M	10:30 A. M.	1 P. M.	4 P. M.
101.3	101.3	100.4	102.3	101.2	103.0	103.0	101.0

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	3 P. M.
101.0	101.0	101.1	104.2	104.3	104.3	105.0	105 0

Injected 8:30 P. M. May 19 with 8 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 6. This steer was part of the show herd at the International Live Stock Exposition in 1909 and was found tubercular at the yearly test a short time after. This is another case where with an interval of six months between tests there was no positive reaction; however, there was enough rise in temperature to make the case a suspicious one. (Test of May 17, 1911.)

This animal gave no reaction to 2 c.c. of tuberculin injected October 9, 1910, this being nullified by the 2 c.c. of the test two days before.

No. 7.—AYRSHIRE HEIFER.

Slaughtered June 29, 1911. Tuberculous. Unfit for food.

December 22, 1910			December 23, 1910			
6 A. M.	8 A. M.	10 A. M.	6 A. M.	8 A. M.	10 A. M.	1 P. M.
101.6	102.6	100.6	105.2	106.4	106.0	105.4

Injected 9 P. M. December 22 with 2 c.c. tuberculin.

March 21, 1911			March 22, 1911				
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
101.4	101.0	101.6	102.8	104.8	105.6	105.2	102.4

Injected 9 P. M. March 21 with 2 c.c. tuberculin.

March 27, 1911			March 28, 1911				
2 P. M.	4 P. M.	6 P. M.	6 A. M.	8 A. M.	10 A. M	12 M.	2 P. M.
101.8	101.2	101.0	103.6	104.8	105.2	103.6	101.6

Injected 9 P. M. March 27 with 6 c.c. tuberculin.

March 30, 1911			March 31, 1911					
8 A. M.	10 A. M.	12 M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.
100.6	100.6	100.6	100.6	100.4	100.6	100.6	100.4	100.4

Injected 9 P. M. March 30 with 12 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.2	101.2	101.6	101.6	101.6	101.8	102.4	103.6

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.2	101.6	102.2	105.0	104.6	104.6	103.6	102.2

Injected 8:30 P. M. May 19 with 12 c.c. tuberculin.
Slaughtered June 29, 1911. Condemned.

No. 7. The feature of interest in this case is in the third and fourth tests. The 6 c.c. of tuberculin was seemingly able to overcome the effect of the injection of 2 c.c. six days before, but the 12 c.c. given three days later was not able to overcome the effects of the previous injections. This case might have passed an ordinary test nearly two months later, as shown by the test of May 17.

No. 8.—ANGUS HEIFER.

Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1910			December 28, 1910			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M
101.2	102.0	101.4	103.0	104.6	105.0	103.8

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.4	100.6	101 8	103.2	103.8	103.0	102.6	102.0

Injected 9:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M	10:30 A. M.	1 P. M	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M
101.2	101.4	100.2	105.0	105.4	104.4	103.8	102.0

Injected 8:30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 9.—SHORTHORN STEER.

Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1910			December 28, 1910			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M.
102.0	100.6	101.8	102.6	103.2	105.2	104 8

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
102.4	102.8	102.4	103.0	103.6	103.6	103.0	103.6

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.8	102.2	102.4	105.2	104.8	102.6	102.2	102.0

Injected 8:30 P. M. May 18 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 10.—SHORTHORN CALF.

Slaughtered June 29, 1911. Tuberculous. Passed for food.

December 27, 1911			December 28, 1911			
8:30 A. M	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M
101.6	102.4	101.6	104.0	105.2	106.4	106.0

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
102.6	101.8	101.8	103.2	105.8	106.2	106.4	105.6

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911			
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.
103.0	103.0	102.8	105.6	105.2	105.2	105.0

Injected 8:30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 11.—SHORTHORN CALF.

December 27, 1911			December 28, 1911			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8:30 A. M.	11 A. M.	1:30 P. M.
101.0	101.0	101.6	104.0	105.2	106.0	106.0

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
101.4	100.6	100.2	104.6	105.6	106.2	106.0	103.4

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M	8 A. M.	10:30 A. M.	1 P. M.	4 P. M.
100.6	101.0	102.8	105.4	105.4	104.6	103.4	104.6

Injected 8:30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Passed for food.

No. 12.—SHORTHORN COW.

Slaughtered June 29, 1911. Tuberculous. Unfit for food.

December 27, 1910			December 28, 1910			
8:30 A. M.	11 A. M.	1:30 P. M.	6 A. M.	8 30 A. M.	11 A. M.	1:30 P. M.
101.8	101.2	101.0	102.2	105.0	105.0	105.4

Injected 9 P. M. December 27 with 2 c.c. tuberculin.

May 17, 1911			May 18, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A M	10:30 A. M.	1 P. M.	4 P. M.
102.0	101.0	101.2	101.8	102.2	103.6	104.2	104.0

Injected 8:30 P. M. May 17 with 2 c.c. tuberculin.

May 19, 1911			May 20, 1911				
8 A. M.	10:30 A. M.	1 P. M.	5:30 A. M.	8 A. M.	10:30 A. M.	1 P. M.	4 P. M
101.6	101.6	101.6	104.8	104.6	103.0	103.0	104.0

Injected 8:30 P. M. May 19 with 6 c.c. tuberculin.
Slaughtered June 29, 1911. Condemned.

Nos. 8, 9, 10, 11, and 12 show the effect of giving a largely increased dose of tuberculin to overcome the influence of the previous injection. In each animal the 6 c.c. was sufficient to overcome the influence of the 2 c.c. That this is not constant is shown in the test of Nos. 1 and 3, where, with the second test following within a week, 5 c.c. failed to give a reaction over the 2 c.c.

It is realized that with the small number of cattle in this experiment the results obtained are not conclusive, but enough data are at hand to show that it is quite possible to nullify the tuberculin test by the prior injection of an ordinary dose of tuberculin; also that the influence of an ordinary dose will last more than 30 days, and that a reliable test can not be expected within 60 days. Doubling the previous dose of tuberculin will usually give a reaction, but this is not sufficiently constant to be relied upon.

It is also shown that an animal may give one or more positive reactions and months later may not react.

SOME INVESTIGATIONS OF THE CEDAR RUST FUNGUS,

Gymnosporangium juniperi-virginianae

By George Herbert Coons

TABLE OF CONTENTS

PAGE

Previous Work on Spore Ejection 217
Life-History of Cedar Rust Fungus 221
Teliospores 222
The Size of Sori and Teliospores 225
Spore Deposits 227
Macroscopic Observations on the Spore Discharge 227
The External Conditions and the Spore Discharge 229
The Projection of Spores 229
The Mechanics of Spore Discharge 232
Discussion of Phylogeny 234
Review of the Cytological Work on the Basidiomycetes 235
Conclusion 237
Summary 237
Bibliography 239

SOME INVESTIGATIONS OF THE CEDAR RUST FUNGUS,

*Gymnosporangium juniperi-virginianae**

By George Herbert Coons

PREVIOUS WORK ON SPORE EJECTION

It has been recently shown by Buller 1909 that the basidiospores of various *Hymenomycetes* are ejected from their sterigmata. The purpose of this paper is to describe a similar condition found in a rust. *Gymnosporangium juniperi-virginianae* Schw., and to discuss the possible bearing of these observations.

That spores were ejected from *Basidiomycetes* with great force had long been suspected and much written about and, as it happens, with more fancy than fact. Bulliard 1791 (p. 51) observed that there was a dispersal of spores from certain *Agaricaceae* in other directions than vertical. Hoffman and De Seynes confirmed the observations of Bulliard by placing a mushroom on its side and noting that the spores were found at some distance from the pileus. MacBride 1885 called attention to a similar observation in which mushrooms under a bell jar dusted over the whole enclosed area.

The white clouds of spores which, rising, look like smoke were often noted in *Polyporus* sp. and had been taken to confirm the idea of forcible ejection of spores. Among the first workers on this genus was Hoffman, who found that if he hung fruiting bodies of *Polyporus destructor* and other *Hymenomycetes* under a bell jar the spores were distributed over a greater circumference than that of the pileus.

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* The department of Agricultural Botany has for some years been engaged in a thoro study of the life-history of *Gymnosporangium juniperi virginianae*. Mr. Coons, while Adjunct Professor of Agricultural Botany undertook the investigation of spore dispersal in this fungus, and the most important results of this study are here presented, while the original paper was presented as a thesis for the degree of Master of Arts.—E Mead Wilcox.

Brefeld described two types of spore ejection. The first of these was described for *Coprinus stercorarius* (Brefeld 1877, p. 65) and in this he describes the ejection to a great distance, relatively speaking. The spores were shot off simultaneously and a small drop of fluid left on the sterigmata. The other type of ejection was described for *Amanita muscaria* (Brefeld 1877, p. 32), and this description has been largely overlooked and only the former description quoted as Brefeld's observation. But in this last case Brefeld states that it is by weak ejection that the spores are freed and drop down in the small chamber between the lamellae.

A writer who has been largely overlooked in this connection is Zalewski 1883, who repeated Brefeld's observation, using other species, and who was, in the main, able to confirm the ejection, but not the details as Brefeld saw them. The observations he made are summed up in the following quotation here given in English since the original work may not be readily available.

"According to this author (Brefeld), all the sterigmata of a given basidium of the fungus simultaneously burst open at the apex, causing the escape of a portion of the contents of the basidium, which collapses, and the spores are thrown off with some force.

"The experiments of this author have been repeated by me on various *Hymenomycetes,* including species of *Agaricus, Coprinus* and *Russula* and *Cantharellus cibarius.* In most cases his results have been confirmed, tho in only a few cases have I been able to witness the discharge of all four spores at once; generally I noted the discharge of one, two, or more rarely three, spores from their sterigmata. In one case two spores were discharged from the basidium of an *Agaricus,* while the other two spores remained attached.

"Brefeld reported that a drop of fluid remained attached to the sterigma after the discharge of the spore. I have never seen this, tho in all cases I have observed a thin streak of fluid following the discharged spore, but no drop of fluid remained attached to the sterigma. Following the discharge of the spores, with the fluid mentioned, the basidium generally collapsed somewhat on one side.

"With the apparatus available I was unable to see any opening remaining at the apex of the sterigma after the discharge of the spore. Perhaps in *Hymenomycetes*, such as *Corticium amorphum*, with large basidia and large spores, this would be possible. The species observed by me had small spores and this opening was evidently quickly closed after the spore discharge, perhaps due to the elasticity of the wall of that part of the sterigma. There can, however, be no doubt that the apex of the sterigma is open at the time of the spore-discharge.

"The discharge of one spore after another from a given basidium would be quite impossible were it not for the closing of the opening in the sterigma either thru the contraction of the membrane or the lodging of some granular material in the opening."

Zalewski's work is worthy of note because he undoubtedly observed the ejection of spores in a great many species of *Agaricaceae*, as well as in lower fungi.

To this list of earlier workers and to those who reported the same sort of ejection of spores the name of Hansen should be added. Hansen reported for *Agaricus* (*Stropharia*) *semiglobatus* the same sort of ejection as Brefeld had reported for *Coprinus stercorarius*. This form ejects its spores at night mostly, only a small fraction being ejected during the day. A fruiting body whose whole stipe was 60 mm. cast its spores 100 mm. He cut a portion from the darkened side of a mushroom and noted that the figure cast was also notched. From this he concluded that the greatest ejection came from the darkened side.

There were then two sorts of spore ejection so far described, the one which dealt with a very strong force by which the spores were shot many centimeters, and the weak ejection in which the spores merely cleared the projecting parts of the lamellae.

The work of Falck in 1902 and 1904 was very clear. Falck found only the weak ejection, and in experiments to determine the other sort of ejection he found only a downward fall of the spores. But his experiments throw great light on the records of Bulliard

and Hoffman and De Seynes. And it is interesting to note that Falck used the beam of light method, later devised independently by Buller. Falck found that the spores were spread evenly about an enclosed chamber from the pilei, and this spreading was not due to a projective force on the part of the mushroom, but due solely to air currents. In this the light and heat relations are the ones especially operative. The ejection is independent of light and gravity, but is stopped by chloroform. Following the ejection the spores fall vertically from their weight until caught up by the swirls of air. By means of insulated chambers Falck was able to prove the generation of heat by the hymenial layer—in some cases the rise in temperature amounting to 6 degrees. By these temperature differences the currents are engendered, and, while not noticeable as currents, they are nevertheless effective in dispersal. Falck discusses this method of liberation for the rusts and shows that when *Gymnosporangium juniperinum* is put in a closed chamber the spores are spread thruout He discusses the significance of this in the production of infection from material upon the ground.

The real proof of the ejection of spores of the *Hymenomycetes* was furnished by Buller 1909, who was able to demonstrate by a series of careful experiments the ejection and fall of spores. For this he devised a method of determining whether spores were falling, by means of a beam of light—a device by which it is possible to see the individual spores moving about quite like motes in the air. Then by cutting small sections of the lamellae of mature mushrooms and mounting in a closed chamber he was able to observe directly with the microscope the ejection and fall of spores.

Buller showed by observation and calculation that the spores are affected enormously by the air resistance and that, while ejected at right angles to the lamellae, before one-half the space between the gills has been traversed the spore is dropping vertically, making a new curve which he dubbed "sporobola." On

issuing from the still air between the gills, the spores are caught by eddies of air and swirled here and there, their weight, however, making them gradually settle to the substratum.

Considering the relation of the spores to the lamellae—that the space between the lamellae is narrow and comparatively speaking extremely deep,—it is of course impossible for the spores to emerge from the inner portions of the gills in any other direction than downward, and it is also obvious that the shooting phenomena described by Bulliard and others were due to air currents—a thing not reckoned with perhaps on account of the fact that the extreme lightness of the spores was not realized.

LIFE-HISTORY OF CEDAR RUST FUNGUS

Gymnosporangium juniperi-virginianae Schw., as is well known from the work of Farlow 1880, 1886; Halsted 1886; Pammel 1905; Sanford 1888; Heald 1909, and others, is a parasite on *Malus* and *Pyrus* spp., on which it forms its aecial stage, and on *Juniperus virginiana*, where it develops its telial form.

The basidiospores from the cedar infect the apple by penetrating the cuticle. Since a statement that the infection takes place thru the stomata inadvertently crept into the paper by Heald 1909, it was thought well to determine the nature of the infection procedure.

Sporidia were sown on the leaves of young "Wealthy" apple grafts, in a drop of water, and the plants kept under bell jars. In five cases the spores were put only on the upper surfaces of the leaves, and in five on the lower surfaces only. Five plants were kept as checks. Greater infection, i. e., production of pycnia and aecia, took place in the cases where the sowings were on the upper surface of the leaves. Since the apple presents few if any stomata on the upper leaf surface, it is evident that the germ-tubes of germinating sporidia penetrate the cuticle. With the microscope it was possible to see the hyphae from the sporidia, after a vagrant, tortuous growth in the water, bend sharply

downward at the edge of the drop and pass into the cells beneath. This last observation was made with leaves washed in sterile water and kept in Petri dishes. These were inoculated in drops of water and marked by circles with the cork borer. Some success was had, too, in inoculation of small green apples.

This observation is quite in harmony with the generalization of Evans 1906, who found that basidiospores penetrated directly, and urediniospores and aeciospores enter thru the stomata.

Heald 1909 showed that the mycelium is perennial in the red cedar, for the galls begin to appear on the twigs before the opening of the aecia—hence the infection that shows up is due to the spores of preceding year. While the actual infection has never been observed, or produced artificially, it is evidently a leaf infection, for the leaves of different stages of swelling can be found, usually showing a swollen center (figs. 1 and 5), or at times a greatly enlarged base with the split portions of the epidermis at the top of the gall.

These galls increase in size during the growing season and in December show small depressed areas. In these the beginnings of the teliospores may be sought. In March these areas begin to show growth; small protrusions gradually occur and as the epidermis finally splits the developing sori emerge. This continues until the sori have reached a length of 5 to 7 mm. (fig. 3).

In the spring, following warm wet weather, these sori swell to from five to ten times their length and increase in diameter at least four times. (Fig. 2.) It is found that they are hollow and that the gelatinous matrix is capable of swelling again and again after drying.

After bearing the sori the galls wither and dry and eventually drop from the trees, but occasionally an old gall will produce sori, but this is believed to be due to a reinfection. (Farlow 1880, p. 15.)

TELIOSPORES

The phases of the life-history with which this work is con-

cerned is the teliospore phase and the succeeding stage, and these therefore will be described in detail.

The teliospores of rusts are characterized generally by being thick-walled, and by the permanent pedicel. (De Bary 1887, p. 279.)

The formation of teliospores has been described in detail by Blackman 1904 (p. 344) for *Gymnosporangium clavariaeforme*. Here it is found that the hyphae, after forming a layer, produce binucleate, rectangular cells which in turn develop several narrow outgrowths. These outgrowths have paired nuclei and undergo two divisions. By these divisions cells are differentiated from the pedicel. The teliospore walls thicken and its cells become filled with an oily reserve material.

In *Gymnosporangium juniperi-virginianae* the teliospores are formed by December and at this time various sizes and stages of telial growth are visible. Sori examined at this time showed depressions marking the location of sori, and a section thru a sorus shows the teliospores all in the same plane. This continues until March, during which month the sori protrude from 5 to 7 millimeters. Sections thru these lengthened sori show that the outer layers of spores are short pedicellate and the succeeding ones longer as one passes inward, and the spores occur only on the surface of the sori, altho there may be several layers of them. This variation in growth and the arrangement is explained by Farlow as a reaction to light and air. (Farlow 1880, p. 10.)

Necessarily such a method of development produces a tubular sorus.

The teliospores are thick-walled and two-celled. The color is orange and is due to the granular contents and the oil. Occasionally in the inner layers of the sorus a spore is found that is thin-walled and somewhat hyalin. Its exact nature has not been worked out. (Blackman 1904, p. 330.)

Very large and distinct oil drops are present in all spores. Sanford 1888 mentions their presence in the mycelia in the

gall. In the early stages of the sorus these drops are circular and are scattered thru the cell. At later stages and in old teliospores these drops coalesce. This is the condition that is shown in dried specimens.

The function of this storage of oil will be dealt with under nutrition phenomena.

The sori of *Gymnosporangium,* as has been said, when wet swell considerably. Then the spores, at ordinary temperature, put forth the promycelia. Farlow states that four germ tubes per cell are produced by this species but no spore has been observed by the writer to develop more than two for each cell and one is a more common number. The process of putting out germ tubes requires from 6 to 15 hours in contrast to "less than 3 hours" as reported by Blackman 1904 (p. 330), for another species of *Gymnosporangium.* Into these germ tubes the granular contents of the cell pass. In one hour the germ tube becomes marked off into four cells, and in another hour spores are produced upon small sterigmata. The granular material of the germ tube passes into the spores but the germ tube remains turgid.

Under certain conditions of moisture and temperature neither spores nor germ tubes are produced. (Heald 1909, p. 108.) An extrusion of the plasm of the cell takes place, which in turn can send out a mycelial tube and probably produce infection. Material gathered on a very cold and rainy day showed in every one of 100 mounts from different sori an absence of normal germ tubes and a great abundance of these so-called abnormal forms.

Some tests were made to determine if the gaseous surroundings had anything to do with the formation of the germ tubes. Spores about to germinate were prevented from germinating by an atmosphere of coal gas, and CO_2. In air that was partly exhausted of oxygen by the pyrogallic acid method the germ tube grew exceedingly long—8 to 10 times the normal length—but produced no sporidia. In all cases when returned to air spores were formed. Blackman 1904 (p. 334) reports extra long

growths of germ tube and absence of sporidia when the spores germinated under water. Sappin-Trouffy 1896 (p. 59), working with *Puccinia malvacearum*, found that submerged promycelial cells separate and put out germ tubes—which must be exposed to air before sporidia are formed.

Frequently on a normal germ tube three spores are produced and the fourth sterigma will protrude, growing perhaps five times as long as the others. Such a case was observed from spores planted on an apple leaf, and this elongated sterigma penetrated the cuticle of the host directly. The spores germinated and produced a rather wavy, thin-walled hyphal net on the surface. It would seem that the germ tube was capable of making a quicker infection than the spores.

In the great majority of cases the promycelium bears four spores upon one side on long sterigmata. When these are formed, the long germ tubes are turgid but entirely void of granular contents. The sterigmata, too, are hyalin. The sterigmata are very pointed and the spores show a prominent "tail" where they are connected.

THE SIZE OF SORI AND TELIOSPORES

The size of cedar-apples varies greatly. Heald 1909 ascribes this to light or heavy infection. It seems, however, rather to be dependent upon the trees, for certain trees of a given locality are always more severely affected than others. However, it is noticed that when practically every branch has a gall the galls are small, but where the effect is scattering the galls are larger.

There are some galls so small that they can accommodate only one or two sori, and there are others on which as many as one hundred are borne. (Fig. 4.) The galls vary in size from 1 mm. in diameter to 5 cm. The prevailing shape is reniform, due, Farlow holds, to the unequal growth of the basal and outer cells.

Sori are usually from 1 to 2 mm. apart and until they are very much swollen do not touch each other. As has been said, they

are very hygroscopic, as is shown by the following table made from measurements taken after soaking the sori for 30 minutes:

TABLE 1.—*Comparison of average dimensions of sori, when dry and when wet.*

Length		Diameter			
		Base		Tip	
Dry	Wet	Dry	Wet	Dry	Wet
7 mm.	13 mm.	1.5 mm.	6 mm.	1 mm.	2.5 mm.

The spores, too, show an increase in size, especially in the pedicels, as is shown by the following table. About 50 spores were put on a slide. These were measured dry. From these spores the wet mount was made and the measurement made after 30 minutes.

TABLE 2.—*Comparison of average dimensions of teliospores, when dry and when wet.*

Width		Length		Diameter pedicel	
Dry	Wet	Dry	Wet	Dry	Wet
15.2 mu	16.5 mu	43.4 mu	48.1 mu	2.8 mu	4.7 mu

Here length and width increase slightly; but the gelatinous pedicel increases nearly 60 per cent. In spite of this great hygroscopic power, the greater part of the increase in bulk of the sorus arises from the jelly-like matrix in which the pedicels are embedded.

The effect of this swelling on the exposure of the sporidia to the wind is, of course, manifest. Each germ tube is accommodated and the adhesion of the spores of adjacent tubes prevented. A view of the sorus when the germ tubes are all extended presents an abatis of sterigmata and spores. The germ tubes are not evident. They are found, however, curling along the sorus, with

the sterigmata growing at right angles. This would seem to be a hydrotropic response.

While in the cedar-apple there is no such large increase of hymenial surface as is found in the *Hymenomycetes* (Falck 1904; Buller 1909, p. 31), yet we have here no mean device for spore dispersal.

SPORE DEPOSITS

It is possible to make spore prints from the sori of *Gymnosporangium* quite as one would make them from the pileus of a mushroom. Air currents must be avoided and drying prevented. This latter condition is more difficult to obtain than with the pileus of a mushroom.

That the spore prints of a mushroom are very beautiful is due to the fact that the spaces between the fan-like gills are reproduced. In the rust we have no such design to follow and so along the length of each sorus a bright orange-colored pile accumulates. A cross-section of a gall including several sori gives a figure comparable to the spore prints from a mushroom fungus. By cutting a sorus transversely and setting it up on end over a pin, or upright support, it is possible to get a ring deposit all around the sorus.

The spores are very adhesive and it is not possible to determine any arrangement in the piles of spores.

These spore prints form an easy way to secure a pure culture of spores for inoculation, since it is possible to secure them upon sterile glassware, free from the moulds, etc., that are invariably present on the sorus, and in infusions made from the sorus.

MACROSCOPIC OBSERVATIONS ON THE SPORE DISCHARGE

Following Buller's device of a beam of light to make the movement of spores visible, results similar to his results on *Agaricaceae* were obtained. However, in dealing with this spore body that was more subject to drying, no such long duration of spore dissemination was observed. However, the phenomenon of re-

viving noticed by him with reference to xerophytic forms was noticed in *Gymnosporangium*, but of course after no such long intervals.

In brief the method followed was this: A gall showing sori well extended and pulverulent with the sporidia was pinned to a sheet of cork over a beaker. A beam of light from an electric arc, passed thru the condensers and a cooling bottle, was sent thru the chamber. Immediately the appearance of motes in the air was observed but all the bodies were the same size. These did not seem to be falling, but were rather swirling about in the air.

Their origin could be traced very readily to the sorus where the number in the air was always larger. The movement of the spores were quite that of the pappus of a thistle in a light breeze. In general one could make out a movement downward.

Here an interesting observation was made. It was noted that a beaker left over night became coated with a yellow deposit. If a large gall was pinned up, the yellowing, while thicker on the bottom, was evenly distributed about the sides. But with a one-sided pinning of the sorus or a drying or injury to one side the beaker became manifestly coated on but one side.

The greatest length of time that the spore fall was observed to continue was two hours, but this same preparation showed next morning a strong yellowing of the sides and bottom of the beaker. Evidently the drifting had taken place for a greater length of time. In the morning no discharge of spores was noticeable.

This same preparation placed in water immediately swelled again and began a spore discharge. Such alternate drying and revival was made three times in all. At the last time there seemed no diminution in the amount of the discharge.

Five months afterwards an attempt was made to revive some galls by soaking them. These were galls that had been collected before the germ tubes were extended. All these attempts were unsuccessful. Perhaps the change in the oil content had something to do with this. This last attempt at revival is, of course,

not comparable to the revival of xerophytic species dealt with by Buller 1909 (p. 105), since the forms are not in the same stage.

THE EXTERNAL CONDITIONS AND THE SPORE DISCHARGE

Light seemed to have no effect on the spore discharge, since it took place either in the daylight or at night, as the piles of spores testified.

Humidity, so long as the promycelium tubes were not desiccated, showed no effect, but the experiments with this were very meagre. The only attempt to affect the humidity was by using a moist beaker and another with the air dried by several grams of $CaCl_2$. For 10 minutes the discharge was observed under each condition, and even following the replacing with the moist beaker no sensible decrease or increase of the number of spores flying was noted.

Temperature and its effects were noted but briefly. The preparation discharges at several degrees above room temperature—the air in the beaker being heated to 30° C. several times in the experiments. A preparation that was discharging spores at room temperature was put into the ice box (7° C.) for 10 minutes and then returned to the beam of light. Spores were discharged as before.

With anaesthetics the same general results that Buller noted were found. A few drops of chloroform were allowed to disappear from the glass and then immediately the sorus was placed in the impregnated atmosphere. Discharge from the sorus ceased immediately. With ether a similar result was obtained.

These results will be discussed in the portion devoted to the Mechanics of the Spore Discharge.

THE PROJECTION OF SPORES

To determine this, four of the methods given by Buller 1909 (p. 133) were used with successful results. These methods will be described in detail.

Exactly as he found the spores of *Hymenomycetes* to be ver adhesive, I found that those of *Gymnosporangium* were likewis so that if spores were discharged against glass or paper it wa fairly impossible to dislodge them. Two spores touching upo the glass after a discharge would draw together and a third an even a fourth would be drawn into place. Hence on the glas when spores were falling, constant readjustment of spores wa taking place.

METHOD I

In the sorus of *Gymnosporangium* it was found that th spores were produced equally upon all sides. A cross section this spore mass was made which gave a ring of gelatinous su stance with the edges almost vertical. This was placed in moist chamber slide and covered with a cover glass. With th low power it was possible to see the spores on the sterigmat bristling out about the whole surface.

Exactly as Buller describes, the apparent shooting of th spores could be seen, not as a distinct view of the spore but a streak of yellow across the view. This could be traced bac to the vacated sterigmata. Focusing downward it was possibl to find the heaps of spores some distance, 200 mu, from the soru

Without Buller's convincing proof of the optical illusion i looking at vertical objects with the microscope,* the strea would have been interpreted as the projectile path of the spor But it was undoubtedly the downward fall of the spore that wa seen. Watching the spores with this in mind it was evident tha the streak began a sensible distance from the sorus.

METHOD II

This method as used in the case of *Gymnosporangium* co sisted in placing one of the active sori horizontally in the mois chamber slide. Then the low power was focused just above som sterigmata. Here it was found that spores springing into vie

* Objects with vertical sides appear to have a trapezoidal shape, hen the spores falling downward appear to be traveling outward.

are seen perfectly for an instant and then disappear. The waits were long with this method and the best results were obtained by focusing on the edge of the sorus.

METHOD III

This method consists essentially in watching the basidia from which the spores are discharging. As in method II, the points of observation selected were at the edges of the sorus and were carefully watched for an hour or so. The eye after following the irregular surface sets up certain landmarks and any change in the topography is noted. Hence it was easy to find areas on the sorus from which spores were being discharged.

As near as could be judged with reference to the origin of the spores as to germ tube, those from a promycelium disappear singly, but within a short time of each other. The sterigmata after the discharge show no collapse but a slight rounding off of the pointed tip. This same rounding off of the pointed attachment was noticeable in the spores.

METHOD IV

This consists in watching the deposit of the spores on the glass about the sorus, having the basidia in focus at the same time. This preparation was in the moist chamber as before, but a very thin ring of the substance was taken. It was possible to have a hazy view of the promycelium and the spores, and where at the start in that particular field only 5 spores were scattered on the glass, at the end of 30 minutes some 40 or 50 were piled up. These occupied a swath about 100 mu wide. The distance of the innermost spore of this pile from the base of the sorus was 260 mu. This measurement was made with the low power. It represents therefore the distance that the spores were expelled. Those spores on the outer edge of the pile were projected 50 to 100 mu farther. Since the spores average about 20 mu in diameter they were projected from 13 to 18 times their length.

It was a most fascinating sight to see the spores arrive an immediately bring about a rearrangement of the positions. I was quite like the bursting of one bubble in a dish, whereupo all the other bubbles rearrange themselves. It was possible b a sharp focus upon the slide to see the "streak" (fall) and th sudden appearance of a new spore.

Methods I, II and III were repeated on a succeeding day wit fresh material from the field. Method IV was possible only th first day and hence only one measurement can be given.

There can be no doubt that *Gymnosporangium juniperi-vi ginianae* Schw. expels its spores as is described for *Hymenomy cetes.*

THE MECHANICS OF SPORE DISCHARGE

Brefeld's observation 1877 on the ejection of the spores o *Coprinus* with the subsequent exudation of a drop of water fro the sterigmata led him to classify the phenomena with the eje tion of spores or spore masses in *Empusa* or *Pilobolus.*

Zalewski 1883, whose results have been quoted rather fully did not find that the spores were ejected simultaneously as a rule, and could see no exudation of the liquid contents of the basidium, but on the contrary he saw a thin stream of wate squirt out and follow the spores. Inasmuch as Buller 1909 has shown that the actual projection is probably too rapid to be seen, and the streak that is seen is the downward path of the spore—appearing by optical illusion as an outward passing— Zalewski no doubt interpreted this as a streaming of a fluid after the spore.

To explain in general the cutting off, and in many forms the ejection, of spores, Zalewski stated that the middle lamella of the wall cutting off the spore gelatinized thru the influence of moisture, allowing the spores to fall or spring off. His observations in so far as they applied to *Albugo* were called in question by Mangin in 1891, who states that the whole intercalary part hydrolizes. De Bary gives Zalewski's views no place in his ex-

planation of the ejection of conidia from the lower forms, but explains the action as the result of twistings and torsions of the dried sporophores due to humidity changes. With reference to the *Hymenomycetes* Zalewski confessed that the sterigmata were too small to allow the hole that Brefeld postulated to be seen, and he was forced to suppose that the sterigma and spore had each of them an elastic membrane which closed the opening, or as an alternative, that the sterigma and spore had very thick and gummy protoplasm. But in his labored explanations he is seeking to harmonize the actual observations which he made with those of Brefeld, for in no case did Zalewski note an exudation of droplets of water. It is not clear why—after Zalewski had shown fairly conclusively that the spores of the lower fungi dropped off due to a hydrolizing of the middle layer—he could not have brought that over for use in the explanation of the cutting off of spores in the higher group. Except of course he had the squirting of the stream of fluid to account for.

Nowakowski gives for *Empusa grylli* the mode of cutting off such as Zalewski describes for *Empusa*, *Peronospora*, and other forms but in addition shows that the force of ejection is furnished by the simultaneous bulging of the walls of the columella and spore. Nowakowski, however, does not utilize the suggestion of Zalewski as to the hydrolysis and subsequent gelatinization of the middle lamella.

Buller inclines to the explanation given by Nowakowski but states that cytological work is necessary to prove the presence of the double wall or of any wall between the sterigma and spore. It is commonly supposed that such a wall is present in the *Basidiomycetes*, and De Bary figures it for *Corticium amorphum*.

It seems evident that the ejection of spores in *Gymnosporangium* is of the same sort as the ejection of spores of the *Hymenomycetes*. It is the ejection of turgid spores from a turgid basidium. The fact that chloroform and ether are able to

stop the ejection seems to show that the phenomenon is one d pendent upon protoplasmic activity, unless vapors in some wa affect the turgor relations. The spores leave one after the oth and there is no collapse of either spores or sterigmata. On th contrary there is a rounding off of the sterigma and a gradu disappearance of the projection on the spore—quite as if th two parts were rounding off in response to a turgor pressur after the restraining connection was broken. The explanatio of Nowakowski therefore seems to be tenable.

DISCUSSION OF PHYLOGENY

The work here reported is not startling in that it does n bring out the need for anything new in arrangement, but it gratifying in that it verifies the result of keen observation Tulasne, sixty years ago. We must, therefore, understand t various positions assigned the rusts in the development of t study of fungi.

Tulasne 1853 placed the *Uredinales* close to the *Hymenomy cetes* on the basis of the homology of the basidium and the ger tube, to which latter he gave the name promycelium.

Brefeld 1888 first placed the *Uredinales* very close to th *Ascomycetes* but later he has taken the position of De Bary, an in this he is followed by the leading mycologists.

De Bary 1853 united the aecial forms with the lichens, and th "*Uredinales*" of that time he placed with the *Hymenomycetes* following Tulasne. Later with the connecting of the aecia stage and the other spore forms—for which he is largely re sponsible—he placed the group between the *Ascomycetes* and th *Hymenomycetes*. In this he traces out a homology in the telio spores and the sporiferous parts of the *Agaricaceae* and a ho mology between the aecium and the ascocarp. With the forme only are we concerned here. In his Comparative Morphology 1887 he says:

"The statements made in former paragraphs show that th

teleutospores, or in some cases perhaps, only the promycelia delevoped from them in the tremelloid *Uredineae,* are not only very like the basidia of the *Tremellineae,* but strictly homologous with them. * * * There is the same relation between the sporidia and the basidiospores.

"The near connection which has been pointed out between the *Hymenomycetes* and the *Uredineae* may well be regarded as an established fact that is not likely to be set aside."

The truth of the keen generalization has been further strengthened by the cytological evidence of which a brief review may be permitted.

REVIEW OF THE CYTOLOGICAL WORK ON THE BASIDIOMYCETES

The present knowledge of the nuclear phenomena of rusts dates from Blackman's classic researches published in 1904 In this work he was verifying the earlier researches of Maire, who had shown that the stages of development in the rusts could be marked off as sporophytic and gametophytic. Blackman was first to show that in the aecium an actual passing of material from one basal cell to another takes place. But fusion of nuclei is delayed until the telial stage, the nuclei dividing side by side in what has been termed conjugate divisions. The details of the conjugation as described by Blackman have been shown by Christman 1905 to be peculiar to certain forms and not universal for the group. But both observers are in harmony on the presence of conjugation and the delayed fusion which follows. Olive 1908 has sought to interpret certain observations of his own to harmonize the work of Blackman and Christman with reference to the nature of the gametes, but Kurssanow 1909 has shown, using *Gymnoconia peckiana,* that the generalizations of Olive are not valid for all rusts.

It would seem then that the present views of the matter indicate a great concordance as to the presence of a conjugation and on the point of its origin. The difference in the reports is with respect to the nature of the gametes—whether isogamous

or heterogamous. This difference is one that concerns itself with theories of algal relationships and does not directly concern us here.

In the higher *Basidiomycetes* there is a striking condition in that the delayed fusion that Blackman found is also present. The peculiar conjugation division of nuclei, where the paired nuclei divide side by side, is also found. The best work in this field of cytology has been done by Wager 1892, Dangeard 1894, Ruhland 1901, Harper 1902, Maire 1903, and Nichols 1904.

Ruhland 1901 found that each hymenial cell had two nuclei. The origin of these nuclei is not known altho it is strongly indicated that a long series of such binucleate cells precede this structure. In the basidium mother cell, the nuclei fuse and by two divisions produce four which pass simultaneously thru the narrow necks of the sterigmata into the spores.

Nichols 1904 found that in the spore each nucleus divides. With the germination of the spores, successive divisions take place in the germ tube, but these divisions are not of the conjugate nature found later when the nuclei are paired. Just at what point in the life-history the paired condition begins is unknown.

Until elucidation of the point of origin of the binucleate condition the similarity with the *Uredinales* can only be inferred. In this regard Harper 1910 (p. 257) says this paired condition "does not apparently result from a cell fusion at a definite point in the life cycle as is the case in the basidium of the rusts" and "it seems probable that the endokaryogamy in the basidium may have functionally replaced an older fusion of differentiated sex cells."

Recently Lutman has shown that in certain *Ustilaginales* the binucleated condition at the stage preliminary to the formation of basidiospores is prevalent and the delayed fusion is most marked, since the sporidia themselves do the conjugating.

Hence there is, so far as the observation has been pushed, this

interesting similarity in nuclear behavior in all the *Basidiomycetes*—this type of intracellular fusion of nuclei after a long period of paired divisions—a thing so striking that this type of fusion has been dignified by the name endokaryogamy.

CONCLUSION

In conclusion, therefore, it may be said, that in the rusts, so far as represented by *Gymnosporangium*, we have a connection with the *Hymenomycetes* shown by some diverse lines of relationship. In the aecium we have a conjugation taking place at a definite point, but clearly establishing a binucleate condition; in the *Hymenomycetes* a quite similar condition but with the definite point of origin lacking or unknown. In the teliospore we have endokaryogamy exactly as pictured in the basidium, and subsequent reduction divisions. In addition to this cytological evidence, there is a striking parallelism of form. This latter thing De Bary has held to be of itself conclusive. Finally, as a piece of additional evidence, we have the ejection of spores identical in each, thus showing, along with this similarity of form and cell behavior, the unity of function.

SUMMARY

Brefeld had observed an ejection of spores in *Coprinus* and Zalewski had repeated the work of Brefeld with a great many species of *Agaricaceae*, but it remained for Falck and Buller to prove conclusively the ejection of spores in the *Hymenomycetes*.

The sporidia infect the apple by penetration of the cuticle and then form pycnia and aecia. The spores from the apple infect the cedar, but, as Heald has shown, the mycelium is perennial in the latter host.

The germination phenomena of the teliospores are briefly reviewed and the abnormalities of germination commented upon.

Measurements are given to show that by the swelling of the

sori and of the pedicels of the spores the hymenial surface is greatly increased, but by no means so extensively as the surface in the *Hymenomycetes.*

It is possible to make spore prints from *Gymnosporangium* quite as from a mushroom and this forms an easy way of securing pure cultures of rust spores.

With the beam of light it is possible to see the spores falling from the sorus.

Light does not seem to affect the spore discharge. Dryness of the atmosphere, so long as the spores and sterigma are turgid does not hinder. Temperature within a range of from 7° C. to 30° C. has no effect. Anaesthetics stop the discharge immediately.

By four methods the discharge of spores was noted. The spores are projected from 13 to 18 times their own length.

The discharge is brought about by the turgor relations of the spore and promycelium (sterigmata), by which a mutual bulging of the parts is produced. That the pressure within the spore and sterigma is high is shown by the fact that both parts round off after the discharge.

The work merely emphasizes the connection between the *Uredinales* and the *Hymenomycetes*—a thing that had long been held on account of the similarity of structure, and which has recently been made sure by a study of the cytology of the groups —by showing that along with this similarity there is a unity of function.

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PLATE I.

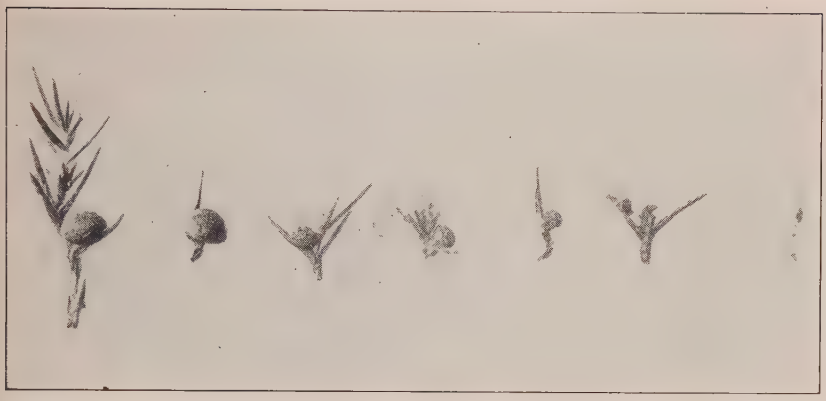

Fig. 1. Series of galls on leaves. × 2.

Fig. 2. Galls with swollen sori.

PLATE II.

Fig. 3. Galls in March; gall of the preceding year at the base.

PLATE III.

Fig. 4. Various sizes of galls—all of which are producing sori.

Fig. 5. Early stages in the development of galls showing their foliar origin.

A STUDY OF THE MOVEMENT OF WATER IN A UNIFORM SOIL UNDER ARTIFICIAL CONDITIONS

By F. J. Alway and V. L. Clark

It is now a well recognized fact that under favorable conditions a considerable amount of water can be stored in the subsoils of semiarid and of arid lands in such a form that it can be carried thru a prolonged dry period and later made use of by crops. This is the explanation of the surprisingly large yields that have been obtained in very dry seasons on fields which in the previous year had been kept under clean cultivation. That this can be duplicated under artificial conditions has been shown at this Experiment Station.[1]

Whether the water thus stored in the subsoil rises to the roots, or the roots penetrate to the stored water, is a question still in dispute, and one on which little experimental data have yet been published. Only a very limited amount of data is yet available as to moisture changes in the subsoil under dry farming conditions. By far the most extensive study of this nature so far published is that by Burr.[2] On various fields and plots at the North Platte Substation he has, beginning with April, 1907, determined the moisture content from month to month and from year to year, thus compiling a history of the subsoil moisture for certain of these fields and plots. The fact that both the soil and the subsoil on the North Platte farm are comparatively uniform—a rare condition on experimental, as well as on other farms—has permitted him to satisfactorily interpret the data which he has accumulated.

If the stored moisture is able to pass freely upward from foot to foot, not only will it move up to the plant roots, in

case these should be confined to the portion of the soil and subsoil near the surface, but it will also reach the surface and evaporate from this unless by some method of cultivation, as for instance by mulching, this can be prevented. If such is the case the character of the surface cultivation will become all important. On the other hand, if there is but little upward movement of moisture from foot to foot, and if there should be occasion to carry stored moisture from one wet season to another thru a prolonged drouth, the dry-land farmer will need to give himself but little concern regarding the condition in which the surface soil is kept, provided only that the growth of all vegetation is prevented. The readiness with which water moves upward will determine, accordingly, whether the dry-land farmer in his attempt to store moisture by clean cultivation should direct his efforts chiefly to keeping the vegetation down or to keeping the surface soil in a certain condition—whichever condition should be found most favorable for conserving water—or whether he should give about equal attention to each.

On most fields it is difficult, from field studies, to draw satisfactory conclusions in regard to the moisture movements, unless the latter be very extensive, for the reason that the soil, from foot to foot, varies so much in properties that it is very difficult to decide, in case the moisture content at one place is found to be higher than at another, whether this is due to a movement of moisture or simply to differences in the particular samples of soil taken. This last-mentioned difficulty can be overcome by the determination of the hygroscopic coefficient of each soil sample taken. This determination, however, has regularly been omitted by almost every soil investigator. Its importance was pointed out by Hilgard long ago, the necessity of its application in moisture studies in the semiarid region was illustrated by one of the writers[3] in 1907, and recently Briggs and Shantz[4] have recognized the necessity for this or

some similar determination. A good illustration of this variability of the soil of individual samples from foot to foot and from boring to boring is indicated in Table 1, which gives the hygroscopic coefficients of soil samples taken from different fields at the same time or from the same field at different times on the H O Ranch near Madrid, Nebraska.

TABLE 1.—*Hygroscopic coefficients of soil samples taken from eleven borings on the H O Ranch.*

Depth	No. 1	No. 2	No 3	No. 4	No. 5	No. 6	No 7.	No. 8	No. 9	No. 10	No. 11
Feet											
1	7.8	8.5	8.0	7.5	7.1	7.4	5.9	8.5	7.0	5.3	1.9
2	10.4	9.8	9.8	10.5	10.4	6.1	6.3	10.2	7.8	5.1	1.8
3	10.2	9.8	11.3	9.2	8.0	7.0	6.4	12.4	9.3	3.3	1.7
4	7.0	8.3	7.7	6.9	6.7	7.2	7.1	13.1	13.0	3.0	1.5
5	7.0	6.9	6.4	6.6	6.3	7.1	7.7	12.2	14.2	3.0	1.8
6	7.8	7.4	6.3	6.9	6.0	9.1	9.3	9.0	12.8	1.9	1.9
7	6.9	....	5.9	4.0	4.1	9.1	11.5	9.4	....	2.7	1.7
8	....	....	5.1	.....	3.9	9.1	9.9	9.2	...	2.2	1.8
9	....	.....	5.9	.....	2.9	7.7	9.0	9.2	.....	3.8	1.5

THE SOIL USED

Having concluded from field studies, the earliest of which have been published,[3] that but little water is lost by direct evaporation from the subsoil below the first 12 inches, we began the first experiment described below to determine the upward movement of water. Later the other related experiments were carried out with some of the same soil. One serious difficulty in the study of the movement of soil moisture under artificial conditions is that with most soils it is difficult, if not actually impossible, to get a soil placed in the cylinders or pots in a condition at all similar to that in which it occurs in the field. For this reason we selected, for the experiments described below, a subsoil that was not only representative of the subsoils of a dry-land farm but also such that it could be placed in cylinders in such a condition as to be very similar to that in which it occurs naturally. Extensive studies of this

soil in pits and borings on the H O Ranch as well as in various cylinder experiments have shown that there is a very close resemblance between the condition of the soil, both in the wet and in the dry state, in the cylinders and the condition of it in the field. This soil was taken from the fourth, fifth, and sixth feet in an excavation made in a prairie field on the H O Ranch. After this subsoil reached the Experiment Station it was thoroly mixed, while dry, by shoveling. The mechanical analysis, hygroscopic coefficient, and maximum water capacity of the soil are given in Table 2. It happens that this soil has a hygroscopic coefficient not much different from the subsoil of the bench portion of the North Platte Farm referred to above. The samples from the North Platte Substation were composites from three borings, taken by one of the writers in 1908 from a prairie pasture on the bench.

TABLE 2.—*Properties of the soil used in the experiments.*

Hygroscopic coefficient	5.6
Maximum water capacity, by Hilgard method	55.0
Maximum water capacity, by Wahnschaffe method	29.9
Mechanical analysis—	*Per cent*
Gravel	2.84
Coarse sand	2.00
Medium sand	1.33
Fine sand	4.16
Very fine sand	67.11
Silt	14.16
Clay*	8.40
Hygroscopic coefficients of soil samples from bench on North Platte Substation farm –	
First foot	7.9
Second foot	6.7
Third foot	6.6
Fourth foot	5.9
Fifth foot	6.1
Sixth foot	6.6

*Determined by difference.

THE EXPERIMENTS

The soil was used in five experiments, employing galvanized iron cylinders of various lengths, to get data on the following:

1. The upward movement of water from moist soil into drier soil.
2. The downward movement from moist soil into drier soil.
3. The loss from saturated soil in contact with the natural subsoil *in situ*.
4. The upward movement in a column of soil, protected from loss below and at the sides, but fully exposed to evaporation at the surface.
5. The downward movement of water applied to the surface of a column of air-dried soil.

In the first and second experiments cylinders closed at the bottom and provided with tight-fitting covers were used. All were 2 feet long and 4 inches in diameter, except three which were 6 feet long and 6 inches in diameter. On starting the second experiment three small holes were made near the bottom of each to permit of the passage of air. These holes were not found to cause any loss of moisture by evaporation into the outside air. In the third experiment the cylinders were 3 feet long, 6 inches in diameter, and open at the bottom but provided with tight-fitting covers. In the fourth experiment they were 3 feet long, 6 inches in diameter, closed at the bottom, and without covers. In the fifth experiment they were 18 inches long, 6 inches in diameter, closed at the bottom, and provided with covers.

METHOD OF FILLING THE CYLINDERS

In experiments 1 and 2 the lower half of each cylinder was filled with soil of known moisture content and the upper half with soil of known but different moisture content. In the first experiment the lower half was the more moist and in the second the upper was the more moist.

The air-dried sample used in Series A to K was that obtained by thoroly mixing a portion of the bulk soil, which had been in contact with the dry air of the storeroom for several months, and placing this in a covered can.

The moister samples were prepared by placing a weighed quantity of the air-dried soil, of which the moisture content had been determined, on the smooth cement floor of the mixing room, and adding the calculated amount of water in small portions while the mass was being shoveled over. The whole of it was mixed thoroly, by first shoveling, then passing it twice thru a swinging sieve of one-fourth-inch mesh, and finally by again shoveling the mass thoroly. The moist soil thus prepared was immediately placed in a large covered can, in which it was kept until transferred to the cylinders. In filling the latter, a small amount of soil was added at a time and this tamped before adding more. For tamping we used a two-inch rubber stopper on the end of a three-eighths-inch gas pipe three feet long. At the time the cylinders were being filled samples were taken from the cans for moisture determinations.

The moisture percentages reported in the tables are those actually found in the soil after it had been mixed and placed in the large cans. Thus, where we desired a series of soils containing 7.0, 9.0, 11.0, 13.0, and 15.0 per cent of water respectively, we obtained, instead, a series with 7.3, 9.1, 11.1, 13.0, and 15.1 per cent, respectively. Those used containing from 5.4 to 6.2 per cent of water were made up with the intention of having the soil contain practically the maximum amount of hygroscopic moisture.

As soon as a cylinder had been filled it was closed by means of the tightly-fitting metal cover. When all the cylinders to be used at one time had been filled, they were weighed on scales sensitive to half an ounce, and placed in a pit dug in the floor of the greenhouse. The pit was covered, a foot and a half below the floor, with boards and straw and then with one foot of soil.

so as to prevent sudden or extreme variations in temperature. There was free circulation of air in the pit, and the soil of the walls and floor was moist. When it was desired to open some of the cylinders the pit was opened, and after the removal of these it was again covered up as before. The cylinders removed were at once weighed in order to determine whether there had been any loss or gain in weight while in the pit. In the case of only two of them did the scales show any change, and these two were rejected. Those placed in the pit at one time were all filled on the same day but those removed from it at one time could not, in some instances, all be opened on the same day. The latter were kept in a constant-temperature room from the time that they were taken from the pit until they were opened.

THE DETERMINATION OF THE MOISTURE

In such an experiment the removal of exactly the desired depth of soil in the case of each cylinder is a very important but difficult operation. In the first two sets the soil was removed by means of a spatula and in the last set by means of an auger provided with a gage so that just one inch at a time was taken. The soil from each inch section, after removal from the cylinder was thoroly mixed and placed in a covered jar. After all the cylinders of a set had been opened, the moisture was determined, thoroly mixing the contents of each jar before removing any soil. Two-hundred-gram samples were dried in aluminum cans in an electric oven kept at 110° C. and thru which a current of air was kept passing. In the first set, all moisture determinations were made in duplicate, but in the later ones only a single moisture determination was made of each inch section. The thoro drying of the samples being extremely important in such a study, we proceeded as follows to insure complete drying: After the samples, fifty to sixty in all, had been in the oven for twelve hours, five or six from different parts of it were removed and allowed to cool in a desiccator. These were weighed, returned to the

oven, and left there for from five to twelve hours longer, when they were again weighed. If no appreciable loss in weight had occurred during the second period of drying, we assumed that all the other samples as well were dry, they having been in the hot oven all the time. If a loss in weight had occurred, however, the drying was continued until two successive weighings showed no appreciable change in weight. After the earlier determinations, instead of using the above method of control, several 200-gram samples taken from a large sample of known moisture content were placed in the oven along with the samples from the cylinders. If, after twelve hours in the oven, these were found to be fully dried the heating was discontinued, but if not they were returned and weighed at intervals of four to twelve hours until thoroly dried, the cylinder samples being left in the oven until the control samples were dry. The former thus had a longer exposure in the oven than the latter. This modification of the control greatly shortened the time required for the drying, as usually the samples were fully dried at the end of twelve hours, thus permitting two charges instead of a single charge to be dried in twenty-four hours.

In all cases the amounts of water are expressed as percentages of the dry soil.

EXPERIMENT 1.—THE UPWARD MOVEMENT OF WATER FROM A MOIST SOIL INTO A DRIER SOIL

A summary of the experiments dealing with this subject is presented in Table 3, while the data are given in detail in Table 4. There were two parts to this experiment. The first consisted of six series of three cylinders each, with a moisture content in the soil of the lower half varying from 8.1 to 16.1 per cent, while the upper half, except in the one series, contained approximately the maximum of hygroscopic moisture. In this odd series the upper half consisted of air-dry soil. The later one consisted of four series of two cylinders each, the soil of the

upper half of each being similar to that of the five series of the first set but the soil of the lower half being much more moist, the water content varying from 17.8 per cent to 27.1 per cent. One cylinder from each of two series of the second set was rejected for the reason given above. In the case of the earlier series one cylinder from each was opened after standing 115 days, while the other two were left undisturbed for 18 to 26 days longer. In the case of the later series one cylinder of each was opened at the end of 62 to 65 days and the other about one month later. The object of leaving part of each series for a longer period was to find whether any considerable movement of water took place after the opening of the first, or whether equilibrium had practically been attained.

Before considering the data in detail, the following irregularities should be pointed out: The cylinders of series A were six feet long and six inches in diameter instead of two feet long and four inches in diameter as were those of all the other series. In cylinder III, in each of Series B, C, D, E, and F, the first two inches were filled with air-dried soil, containing 3.3 per cent of water. In obtaining an average for the three cylinders of these series, the data from each of these are used along with those from the other two, as the error thereby introduced, amounting to only 0.1 per cent in the average of the whole, is negligible, altho on the average moisture content of the cylinder itself it causes an error of 0.2 per cent in the apparent change of water content. As may be seen from the tables, the average moisture content for each cylinder, as determined at the end of the experiment, indicates that in some cases there had been a slight loss and in others a slight gain between the time that the moist soil was placed in the large covered cans already referred to and the time that it was weighed out into the aluminum cans for the final moisture determinations. In some cases the apparent loss amounts to 0.5 per cent, while in others there is an apparent gain of 0.2 to 0.4 per cent. As all the cylinders reported were

weighed just after being filled and again just before being opened, and as none of them showed any change in weight on scales sensitive to half an ounce, while the weight of the soil in each amounted to 15.3 to 16.9 pounds, the maximum actual loss or gain of moisture which took place while the cylinders were in the pit must have been less than 0.3 per cent. Incomplete drying of either the samples used in filling the cylinders or of those removed from the cylinders would have caused such variations, but the precautions taken, as described above, should have excluded errors from this source. This seeming gain or loss of water is rather to be attributed to the upper foot sections not weighing the same as the lower foot sections and the twenty-four samples taken on opening a cylinder varying considerably in the weight of dry soil. For this reason the actual average moisture content of the soil of the whole cylinder would not be that obtained by taking the average of the moisture contents found for the different sections. Slight losses of moisture may be attributed to evaporation occurring while the moist soil was being transferred from the large cans to the cylinders, and again at the close of the experiments, when it was being transferred from the cylinders to the jars, the air of the room in which this work was done being very dry. The instances in which a loss is shown, in both Tables 3 and 5, are more numerous than those in which a gain appears.

During the period intervening between the opening of the first of each series and the opening of the others no distinct movement of water is shown. In some series the upper foot of soil was more moist in the cylinder opened first than in that opened later, while in others the reverse was true. Hence, it is probable that equilibrium had been practically attained in the two-foot cylinders before the first was opened—at least in so far as would concern the length of time included in a single crop season. In the case of II and III of Series A, in which the cylinders were six feet long, there was, during the last 26 days, a slight but

distinct, upward movement of water, but in these equilibrium could not be attained until the water content of all the soil of the upper three feet had reached 5.6 per cent—the hygroscopic coefficient.

The two-inch layer of air-dried soil at the top of III of Series B, C, D, E, and F had taken up the maximum, or almost the maximum, of hygroscopic moisture during the period of exposure.

Series A. The air-dry soil in the upper half of each cylinder had gained much in moisture, but in no part of it had the moisture content reached the hygroscopic coefficient. To furnish this water, the uppermost two inches of the lower three feet had been reduced almost to the hygroscopic coefficient. Thus a soil in excellent condition of moisture for a seed-bed had, when protected by a three-foot mulch of air-dry soil, been so dried out to a depth of three inches that seeds would not have been able to germinate in it—dried out, not by the air, but by the mulch.

Series B. With 6.1 per cent above and 8.1 per cent below, the change in the water content was limited to the portion of the soil column within three inches below and two inches above the original dividing line, except that an appreciable decrease in moisture at the top of the soil column, and a corresponding increase at the bottom, is shown.

Series C. With 6.1 per cent above and 10.1 per cent below, there had been no important change at a greater distance than five inches on each side of the original dividing line.

Series D. With 6.1 per cent above and 12.1 per cent below, an upward movement of water took place from the whole of the lower foot, affecting the dry soil above to a distance of 5 or 6 inches. In cylinder No. I there was an increase in moisture (2.0 per cent) in the upper four inches of the cylinder.

Series E. With 6.1 per cent above and 14.1 per cent below, there was an increase thruout the upper foot and an almost uni-

form decrease thruout the lower foot. An increase of 1.0 per cent or more occurred to only five inches above the original dividing line in two cylinders, but to the surface in the other.

Series F. With 5.9 per cent above and 16.1 per cent below, there was an almost uniform loss of 2.0 per cent thruout the lower foot and a general, but not uniform, movement thruout the upper foot.

Series G. With 6.2 per cent above and 17.8 per cent below, there was a comparatively uniform loss of about 2.2 per cent of water thruout the lower foot.

Series H. With 6.2 per cent above and 22.8 per cent below, there was an almost uniform upward movement from the lower foot of about 4.0 per cent of water. The corresponding gain in the upper foot extended to the surface but was less uniform than the change in the lower foot.

Series I. With 6.2 per cent above and 25.4 per cent below, the movement of moisture was similar to that in the preceding series but more extensive, amounting to 5.0 per cent in the lower foot.

Series J. With 6.2 per cent above and 27.1 per cent below the movement was similar to that in the preceding two series but still more extensive.

To summarize the results, it may be stated that with 10.1 per cent of water in the lower foot little upward movement took place, but with 12.1 per cent there was a distinct uniform movement of about 1.0 per cent, with 14.2 of about 1.8, with 16.1 of about 2.0, with 17.8 of about 2.2, with 22.8 of about 4.0, with 25.4 of about 5.0, and with 27.1 of about 6.0 per cent.

The most striking characteristic of the upward movement of water was the uniformity of the loss thruout the lower foot where the initial water content of this had exceeded 11 per cent. If roots had extended to the top of a foot section of the soil they could, without having entered the section, have reduced the moisture content uniformly to about 11 per cent.

TABLE 3.—*Summary of data on experiments on the upward movement of water.*

Series	Cylinder No.	Date of filling	Date of opening	Time	Initial water content			Final water content			Change in water content		
					1-12 in.	13-24 in.	1-24 in.	1-12 in.	13-24 in.	1-24 in.	1-24 in.	13-24 in.	1-24 in.
				Days	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
A*	I	Sept. 3, 1910	Dec. 26, 1910	115	3.3	10.2	6.7	3.9	8.5	6.2†	.6	1.7	—.5†
	II	Sept. 3, 1910	Jan. 21, 1911	141	3.3	10.2	6.7	4.0	8.3	6.2†	.7	1.9	.5†
	III	Sept. 3, 1910	Jan. 21, 1911	141	3.3	10.2	6.7	4.2	8.3	6.3†	.9	1.9	—.4†
B	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	8.1	7.1	6.2	8.2	7.2	.1	.1	—.1
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	8.1	7.1	5.9	8.0	7.0	— .1	— .1	—.1
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	8.1	7.1	5.7	7.8	6.8	— .4	— .3	—.3§
C	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	10.1	8.1	6.4	9.8	8.1	.3	— .3	.0
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	10.1	8.1	6.2	9.7	7.9	.1	— .4	—.2
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	10.1	8.1	6.0	9.5	7.8	— .1	— .6	—.3§
D	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	12.1	9.1	6.7	11.0	8.9	.6	—1.1	—.2
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	12.1	9.1	7.4	11.0	9.2	1.3	—1.1	.1
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	12.1	9.1	6.4	10.7	8.6	.3	—1.4	—.5§
E	I	Sept. 3, 1910	Dec. 26, 1910	115	6.1	14.2	10.1	8.7	12.0	10.3	2.6	—2.2	.2
	II	Sept. 3, 1910	Jan. 13, 1911	133	6.1	14.2	10.1	7.3	12.3	9.8	1.2	—1.9	—.3
	III	Sept. 3, 1910	Jan. 13, 1911	133	6.1‡	14.2	10.1	7.1	12.4	9.8	1.0	—1.8	—.3§
F	I	Sept. 3, 1910	Dec. 26, 1910	115	5.9	16.1	11.0	8.0	13.4	10.7	2.1	—2.7	—.3
	II	Sept. 3, 1910	Jan. 13, 1911	133	5.9	16.1	11.0	8.7	14.1	11.4	2.8	—2.0	.4
	III	Sept. 3, 1910	Jan. 13, 1911	133	5.9‡	16.1	11.0	8.1	14.0	11.0	2.2	—2.1	.0§
G	I	Dec. 20, 1911	Feb. 20, 1912	62	6.2	17.8	12.0	8.3	15.5	11.9	2.1	—2.3	—.1
H	I	Dec. 20, 1911	Feb. 21, 1912	63	6.2	22.8	14.5	10.1	18.9	14.5	3 9	—3.9	.0
I	I	Dec. 20, 1911	Feb. 23, 1912	65	6.2	25.4	15.8	10.0	20.2	15.1	3.8	—5.2	—.7
	II	Dec. 20, 1911	March 29, 1912	100	6.2	25.4	15.8	11.4	20.5	15.9	5.2	—4.9	.1
J	I	Dec. 20, 1911	Feb. 22, 1912	64	6.2	27.1	16.6	12.3	21.1	16.7	6.1	—6.0	.1
	II	Dec. 20, 1911	March 27, 1912	98	6.2	27.1	16.6	11.8	21.1	16.4	5.6	—6.0	—.2

*The three cylinders of this series were each 6 feet long. The data given are for the third and fourth feet.
†The changes for the whole 6 feet were 0.0, 0 2 and 0.2 per cent, respectively.
‡The uppermost two inches of this cylinder contained originally only 3.3 per cent water instead of the same as the rest of the foot.
§An apparent loss of 0.2 to 0.3 per cent is explained by ‡.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil.*

SERIES A.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 21	Cyl. III Jan. 21	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 to 3*	3.3	3.5	3.5	3 7	3.6	.....	0.3
4 to 6	3.3	3.5	3.5	3.8	3 6	.....	0.3
7 to 9	3.3	3.5	3.5	3.7	3.6	.....	0.3
10 to 12	3.3	3.5	3.4	3.6	3.5	.....	0.2
13 to 15	3.3	3.4	3.4	3.6	3.5	.....	0 2
16 to 18	3.3	3.4	3.4	3.6	3.5	.....	0.2
19 to 21	3.3	3.4	3 5	3.6	3.5	.....	0.2
22 to 24	3.3	3.4	3.5	3.6	3.5	.....	0 2
25 to 27	3.3	3.4	3.7	3.7	3 6	.....	0.3
28 to 30	3.3	3.7	3.8	4.1	3.9	.....	0.6
31 to 33	3.3	4.0	4.1	4 3	4.1	.....	0.8
34	3.3	4.2	4.2	4.4	4.3	.....	1.0
35	3.3	4.5	4 5	4.8	4.6	.....	1.3
36	3.3	4.8	4.8	4.9	4.8	.....	1.5
37	10.2	5.5	5 0	5.6	5.4	4.8	.....
38	10.2	6 0	6 2	5.6	5.9	4.3	.....
39	10.2	7.3	6.2	6.5	6.7	3 5	.....
40	10.2	9.0	8.7	8.3	8.7	1 5	.....
41	10.2	9.1	8.9	8.9	9.0	1.2	.....
42	10.2	9.2	9.0	8.9	9.0	1.2	.....
43	10.2	9.2	9.0	9.2	9.1	1.1	.....
44	10.2	9.3	9.2	9.3	9.3	0.9	.....
45	10.2	9.3	9.2	9.3	9.3	0.9	.....
46	10.2	9.3	9.3	9.3	9.3	0.9	.....
47	10.2	9.4	9.4	9.4	9.4	0.8	.....
48	10.2	9.4	9.4	9.4	9.4	0.8	.....
49	10 2	9.5	9.6	9.5	9.5	0 7	.....
50	10.2	9.5	9.6	9.6	9.6	0.6	.....
51	10.2	9.5	9 7	9 6	9.6	0 6	.....
52	10.2	9.5	9.8	9.7	9.7	0.5	.....
53	10.2	9.7	9.7	9.8	9.7	0.5	.....
54	10 2	9.8	9.8	9.8	9.8	0.4	.....
55	10.2	9.8	9.9	9.8	9.8	0.4	.....
56	10.2	9 8	9.9	9.8	9.8	0.4	.....
57	10.2	9.9	9 9	9.9	9.9	0.3	.....
58	10.2	10.0	9.9	10.0	10.0	0.2	.....
59	10.2	10.0	10.0	10 0	10.0	0 2	.....
60	10.2	10.0	10.0	1 .0	10.0	0.2	.....
61 to 63*	10.2	10.0	10.1	10.1	10.1	0.1	.....
64 to 66	10 2	10.0	10.1	10.1	10.1	0.1	.....
67 to 69	10 2	10.0	10.2	10.1	10.1	0.1	.....
70 to 72	10.2	10.0	10.2	10.2	10.1	0.1	.....
Average	6.7	6 7	6.9	6.9	6.8	.....	.....

*Inclusive.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES B.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 6	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	5.5	4.9†	5.4	0.7	.....
2	6.1	6.0	5.7	4.9†	5.9	0.2	.....
3	6.1	5.7	5.7	5.3	5.6	0.5	.....
4	6.1	5.9	5.7	5.5	5.7	0.5	.....
5	6.1	6.0	5.8	5.6	5.8	0.3	.....
6	6.1	6.0	5.9	5.7	5.9	0.2	.....
7	6.1	6.2	5.9	5.7	5.9	0.2	.....
8	6.1	6.2	6.0	5.9	6.0	0.1	.....
9	6.1	6.2	6.0	6.0	6.1	0.0	.....
10	6.1	6.4	6.1	6.2	6.2	.....	0.1
11	6.1	6.6	6.3	6.3	6.4	.....	0.3
12	6.1	7.0	6.7	6.9	6.9	.....	0.8
13	8.1	7.5	6.9	7.3	7.2	0.9	.....
14	8.1	7.7	7.7	7.3	7.6	0.5	.....
15	8.1	7.8	7.8	7.4	7.7	0.4	.....
16	8.1	8.1	7.8	7.6	7.8	0.3	.....
17	8.1	8.1	7.9	7.7	7.9	0.2	.....
18	8.1	8.2	8.0	7.7	8.0	0.1	.....
19	8.1	8.2	8.0	7.9	8.0	0.1	.....
20	8.1	8.2	8.1	7.9	8.1	0.0	.....
21	8.1	8.3	8.3	7.9	8.2	.....	0.1
22	8.1	8.6	8.4	8.0	8.3	.....	0.2
23	8.1	8.6	8.5	8.1	8.4	.....	0.3
24	8.1	8.7	8.6	8.3	8.5	.....	0.4
Average	7.1	7.2	7.0	6.8	6.9	.....	.....

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

† The upper two inches were used as a composite for the determination of moisture.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES C.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	5.4	5.3	5.5	0.6	.....
2	6.1	5.8	5.5	5.3	5.5	0.6	.....
3	6.1	5.9	5.6	5.4	5.7	0.4	.....
4	6.1	5.9	5.7	5.5	5.7	0.4	.....
5	6.1	5.9	5.7	5.6	5.7	0.4	.....
6	6.1	6.2	5.8	5.7	5.9	0.2	.....
7	6.1	6.3	6.0	5.8	6.0	0.1	.....
8	6.1	6.4	6.1	6.0	6.2	.....	0.1
9	6.1	6.5	6.3	6.3	6.4	.....	0.3
10	6.1	6.9	6.9	6.5	6.8	.....	0.7
11	6.1	7.3	7.2	7.0	7.2	.....	1.1
12	6.1	7.6	7.7	7.5	7.6	.....	1.5
13	10.1	9.2	9.3	7.8	8.8	1.3	.....
14	10.1	9.7	9.6	9.4	9.6	0.5	.....
15	10.1	9.8	9.6	9.5	9.6	0.5	.....
16	10.1	9.8	9.6	9.5	9.6	0.5	.....
17	10.1	9.8	9.6	9.6	9.7	0.4	.....
18	10.1	9.8	9.7	9.8	9.8	0.3	.....
19	10.1	9.9	9.6	9.8	9.8	0.3	.....
20	10.1	9.9	9.7	9.8	9.8	0.3	.....
21	10.1	9.9	9.8	9.8	9.8	0.3	.....
22	10.1	9.9	9.8	9.8	9.8	0.3	.....
23	10.1	9.9	9.8	9.8	9.8	0.3	.....
24	10.1	9.9	9.9	9.9	9.9	0.2	.....
Average	8.1	8.1	7.9	7.8	7.9	.....	.....

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES D.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	5.7	8.1	5.4	6.4		0.3
2	6.1	5.7	7.6	5.4	6.2		0.1
3	6.1	5.9	8.1	5.6	6.9		0.8
4	6.1	6.1	7.3	5.7	6.4		0 3
5	6.1	6.2	6.5	5.8	6.2		0.1
6	6.1	6.3	6.3	6.0	6.2		0.1
7	6.1	6.6	6.5	6.1	6.4		0.3
8	6.1	6.9	6.7	6.4	6.7		0.6
9	6.1	7.2	7.3	6.9	7.1		1.0
10	6.1	7.6	7.7	7.3	7.5		1.4
11	6.1	8.1	8.2	7.6	7.9		1.8
12	6.1	8.5	8.6	8.2	8 4		2.3
13	12 1	9.0	9.0	8.9	9.0	3.1	
14	12.1	11.0	11.0	9.9	10 6	1.5	
15	12.1	11.1	11.1	11.0	11.1	1.0	
16	12.1	11.1	11.1	11.0	11.1	1.0	
17	12.1	11.1	11.2	10.9	11.1	1.0	
18	12.1	11.1	11.2	10.9	11.1	1.0	
19	12.1	11.1	11.1	10.9	11.0	1.1	
20	12.1	11.1	11.2	10.9	11.1	1.0	
21	12.1	11.2	11.2	11.0	11.1	1.0	
22	12.1	11.2	11.2	11.1	11.2	0.9	
23	12.1	11.2	11.2	11.1	11.2	0 9	
24	12.1	11.4	11.2	11.0	11.2	0.9	
Average	9.1	8.9	9.2	8.6	8.9		

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES E.

Depth of section	Cyls. I to III Sept. 3	Cyl I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.1*	7.6	6.4	5.8	6.6	.....	0.5
2	6.1	7.7	6.6	5.9	6.7	.....	0.6
3	6.1	7.7	6 5	6.1	6.8	.....	0.7
4	6.1	7.7	6.1	6.2	6.7	.....	0.6
5	6.1	7.5	6.2	6.3	6.7	.....	0.6
6	6.1	7.4	6.4	6.4	6.7	.....	0 6
7	6.1	7.5	6.6	6.8	6.8	.....	0.7
8	6.1	8.0	7.3	7.4	7.6	.....	1.5
9	6.1	8.1	8.6	8.0	8.1	.....	2.0
10	6.1	8.7	8.4	8.4	8.5	.....	2.4
11	6.1	9.2	8.9	8.8	9.0	.....	2.9
12	6.1	9.3	9.2	9.0	9.2	.....	3.0
13	14.2	10.3	9.8	9.5	9.9	4.3	.....
14	14.2	12.4	11.6	11.0	11.7	2.5	.....
15	14.2	12.5	11.7	12.6	12.2	2.0	.....
16	14.2	12.8	12.5	12.8	12.7	1.5	.....
17	14.2	12.8	12.6	12.8	12.7	1.5	.....
18	14.2	12.8	12.8	12.8	12.8	1.4	.....
19	14.2	12.8	12.6	12.8	12.7	1.5	.....
20	14.2	12 8	12.8	12.8	12.8	1.4	.....
21	14.2	12.8	12.7	12.8	12.8	1.4	.....
22	14 2	12 8	12 8	12.8	12.8	1.4	.....
23	14.2	12 8	12.8	12.7	12.8	1.4	.....
24	14.2	12.8	12.7	12.8	12.8	1.4	.....
Average	10.1	10.3	9.8	9.8	10.0	.....	.....

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.3 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES F.

Depth of section	Cyls. I to III Sept. 3	Cyl. I Dec. 26	Cyl. II Jan. 13	Cyl. III Jan. 13	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	5.9*	7.2	7.1	6.7	7.0		1.1
2	5.9	7.2	7.5	6.6	7.1		1.2
3	5.9	7.1	7.5	6.6	7.1		1.2
4	5.9	7.1	7.7	6.9	7.2		1 3
5	5.9	7.0	8.2	7.3	7.5		1.6
6	5.9	7.4	8.7	7.6	7.9		2.0
7	5.9	8.0	9.0	7.8	8.3		2.4
8	5.9	8.4	9.3	8.9	8.9		3.0
9	5.9	8.6	9.5	9.2	9.1		3.2
10	5.9	8.8	9.8	9.5	9.4		3.5
11	5.9	9.3	10.0	9.8	9.7		3.8
12	5.9	9.7	10.5	10.0	10.1		4.2
13	16.1	10.1	13.7	12.7	12.2	3.9	
14	16.1	11.2	13.9	13.8	13.0	3.1	
15	16.1	13.5	14.0	14.2	13.7	2.4	
16	16.1	13.8	14.1	14.2	14.0	2.1	
17	16.1	14.1	14 2	14.0	14.1	2.0	
18	16.1	14.0	14 2	14.1	14 1	2.0	
19	16.1	13.9	14.3	14.0	14.0	2.1	
20	16.1	13.9	14 2	14.2	14.1	2.0	
21	16.1	14.2	14.2	14 2	14 2	1.9	
22	16.1	14.3	14.3	14.6	14.4	1.7	
23	16.1	13.9	14 3	14.0	14.1	2.0	
24	16.1	13.9	14.3	14.2	14.1	2.0	
Average	11.0	10.7	11.4	11.0	11.0		

* The upper two inches of cylinder III were filled with air-dried soil carrying 3.8 per cent of water.

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

Depth of section	SERIES G, Cyl. I				SERIES H, Cyl. I			
	Dec. 20	Feb. 20	Loss	Gain	Dec. 20	Feb. 21	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.2	5.6	0 6	.....	6.2	9.0	.....	2 8
2	6.2	5.8	0.4	.....	6.2	9.2	.....	3.0
3	6.2	5.9	0.3	.....	6.2	9.1	.....	2.9
4	6.2	6.3	.....	0.1	6.2	9.2	.....	3.0
5	6.2	7.0	.....	0.8	6.2	9.3	.....	3.1
6	6.2	7.9	.....	1.7	6.2	9.5	.....	3.3
7	6.2	8.7	.....	2.5	6.2	9.8	.....	3.6
8	6 2	9.3	.....	3.1	6.2	10.1	.....	3.9
9	6.2	9.8	.....	3.6	6.2	10.6	.....	4.4
10	6.2	10.3	.....	4.1	6 2	11.1	.....	4.9
11	6.2	10.7	.....	4 5	6.2	11 5	.....	5.3
12	6.2	12.5	.....	6.3	6.2	13.9	.....	7.7
13	17.8	15.4	2.4	.....	22.8	17.5	3.3	.....
14	17.8	15.6	2.2	.....	22.8	18.7	4.1	.....
15	17.8	15.2	2.6	.....	22.8	18.8	4 0	.....
16	17.8	15.4	2.4	.....	22.8	19 1	3.7	.....
17	17.8	15.5	2.3	.....	22.8	19.2	3.6	.....
18	17.8	15.5	2.3	.....	22.8	19.2	3.6	.....
19	17.8	15.7	2.1	.....	22.8	19.0	3.8	.....
20	17.8	15.6	2.2	.....	22.8	19.2	3.6	.....
21	17.8	15.6	2.0	.....	22 8	19.1	3.7	.....
22	17.8	15.7	2.1	.....	22.8	19.2	3 6	.....
23	17.8	15.6	2.2	.....	22.8	19.2	3.6	.....
24	17.8	15.6	2.2	.....	22.8	18.8	4.0	.....
Average	12.0	11.9	.....	.....	14.5	14.5	.....	

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Continued.*

SERIES I.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 23	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.2	6.8	9.7	8.3	.....	2.1
2	6.2	7.4	9.8	8.8	.....	2.6
3	6.2	8.1	9.9	9.0	.....	2.8
4	6.2	8.8	10.2	9.5	.....	3.3
5	6.2	9.4	10.4	9.9	.....	3.7
6	6.2	9.9	10.7	10.3	.....	4.1
7	6.2	10.2	10.9	10.5	.....	4.3
8	6.2	10.7	11.4	11 0	.....	4.8
9	6.2	10.9	11.7	11.3	.....	5.1
10	6.2	11.3	11.9	11.6	.....	5.4
11	6.2	11.7	12.8	12.2	.....	6.0
12	6.2	14.9	16.9	15.9	.....	9 7
13	25.4	19.2	19.7	19.4	6.0	.....
14	25.4	20.2	20.3	20.2	5.2	.....
15	25.4	20.2	20.1	20 2	5.2	.....
16	25.4	20.2	20.0	20.1	5.3	.....
17	25.4	20.4	20.7	20.5	4.9	.....
18	25.4	20.3	20.5	20.4	5.0	.....
19	25.4	20.4	20.4	20.4	5.0	.....
20	25.4	20.4	20.7	20.5	4.9	.....
21	25.4	20.6	20.6	20.6	4.8	.....
22	25.4	20.8	20.8	20.8	4.6	.....
23	25.4	20.8	20 7	20.8	4.6	.....
24	25.4	20.3	21.5	20.9	4.5	.....
Average	15.8	15.1	15.9	15.5	.....	.....

TABLE 4.—*The upward movement of water from a moist soil into a drier soil—Concluded.*

SERIES J.

Depth of section	Cyls. I, II Dec. 20	Cyl I Feb. 22	Cyl. II March 27	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	6.2	10.5	10.7	10.6	.....	4.4
2	6.2	10.7	10.9	10.8	.....	4.6
3	6.2	10.8	10.8	10.8	.....	4.6
4	6 2	11.0	Lost	11.0	.....	4.8
5	6.2	11.0	10 9	11.0	.....	4.8
6	6.2	11.4	11.1	11.2	.....	5.0
7	6.2	12.0	11.2	11.6	.....	5.4
8	6.2	12.2	11.6	11.9	.....	5.7
9	6.2	12.7	11.9	12.3	.....	6.1
10	6.2	12.9	12.3	12.6	.....	6 4
11	6.2	13.8	12.6	13.2	.....	7.0
12	6.2	18 6	16.3	17.4	.....	11.2
13	27.1	20.9	19.3	20.1	7.0	.....
14	27.1	21.0	20.5	20.7	6.4	.....
15	27.1	21.1	20.5	20.8	6.3	.....
16	27.1	21.1	20.6	20.8	6.3	.....
17	27.1	21.1	21.1	21.1	6.0	.....
18	27.1	21.1	21.5	21.3	5.8	.....
19	27.1	21.1	21.5	21.3	5.8	.....
20	27.1	21.2	21.9	21.5	5.6	.....
21	27.1	21.3	21.8	21.5	5.6	.....
22	27.1	21.3	21.5	21 4	5.7	.....
23	27.1	21.4	21.6	21.5	5.6	.....
24	27.1	21.1	21.2	21.1	6.0	.....
Average	16.7	16.7	16.4	16.6	.....	.....

EXPERIMENT 2.—THE DOWNWARD MOVEMENT OF WATER FROM A MOIST SOIL INTO A DRIER SOIL

A summary of the experiments dealing with this is given in Table 5 and the data in detail in Table 6. As in the preceding experiment, there were two parts, the earlier consisting of six series of three cylinders each with a moisture content in the soil of the upper half varying from 7.3 per cent to 15.1 per cent, while that of the lower half was 5.4 per cent, except in one series where it was only 3.4 per cent. The later part consisted of five series of two cylinders each, the moisture content of the soil of the upper half varying from 15.8 to 27.1 per cent. One of the cylinders of each series was opened some time before the others of the same series.

Here, also, the average moisture content at the close indicated a gain in some cylinders and a loss in others during the course of the experiment.

In the earlier series, K to P, the soil was removed in two-inch sections instead of in inch sections.

In this experiment also there was little or no distinct movement of water downward during the interval that elapsed between the opening of the first cylinder of each series and that of the others, indicating that equilibrium had been practically attained before the first was opened.

Series K. With 9.4 per cent above and 3.4 per cent below, there was a comparatively uniform loss of 2 per cent thruout the upper foot and a gain thruout the lower foot, but not enough to raise the moisture of the latter to the hygroscopic coefficient.

Series L. With 7.3 per cent above and 5.4 per cent below, the movement was very slight.

Series M. With 9.1 per cent above and 5.4 per cent below, there was a uniform loss of about 1 per cent from the upper foot.

Series N. With 11.0 per cent above and 5.4 per cent below, there was 1.3 per cent loss from the upper foot and a gain of 1.0 per cent thruout the upper third of the lower foot but the movement did not extend below three inches.

Series O. With 13.0 per cent above and 5.4 per cent below, there was a uniform loss of about 2.0 per cent from the upper foot.

Series P. With 15.1 per cent above and 5.4 per cent below, there was a loss of 2.5 per cent or more thruout the upper foot.

Series Q. With 15.8 per cent, the foot section lost uniformly about 2.3 per cent.

Series R. With 17.8 per cent, the foot section lost uniformly about 3.0 per cent.

Series S. With 22.8 per cent, the loss reached 4.7 per cent.

Series T. With 25.4 per cent, the loss reached 5.3 per cent.

Series U. With 27.1 per cent, it reached 6.7 per cent.

On opening the cylinders the moisture in the upper foot was in all series comparatively uniformly distributed and that in the lower foot was more uniform than was the case in the upper foot in the series of the preceding experiment.

TABLE 5.—*Summary of data on experiments on the downward movement of water.*

Series	Cylinder No.	Date of filling	Date of opening	Time	Initial water content			Final water content			Change in water content		
					1-12 in.	13-24 in.	1-24 in.	1-12 in.	13-24 in.	1-24 in.	1-24 in.	13-24 in.	1-24 in.
				Days	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*
K	I	Jan. 28, 1911	April 26, 1911	88	9.4	3.4	6.4	7.6	4.4	6.0	—1.8	1.0	—0.4
	II	Jan. 28, 1911	May 2, 1911	94	9.4	3.4	6.4	7.5	4.1	5.8	—1.9	0.7	—0.6
	III	Jan. 28, 1911	May 2, 1911	94	9.4	3.4	6.4	7.5	4.3	5.9	—1.9	0.9	-0.5
L	I	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.7	6.1	—0.8	0.3	—0.2
	II	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.7	6.1	—0.8	0.3	-0.2
	III	Jan. 28, 1911	April 26, 1911	88	7.3	5.4	6.3	6.5	5.6	6.0	-0.8	0.2	—0.3
M	I	Jan. 28, 1911	April 26, 1911	88	9.1	5.4	7.2	8.0	5.7	6.8	—1.1	0.3	—0.4
	II	Jan. 28, 1911	May 2, 1911	94	9.1	5.4	7.2	8.0	5.9	7.0	—1.1	0.5	—0.2
	III	Jan. 28, 1911	May 2, 1911	94	9.1	5.4	7.2	8.2	6.0	7.1	—0.9	0.6	—0.1
N	I	Jan. 28, 1911	April 26, 1911	88	11.1	5.4	8.2	9.5	6.0	7.8	—1.5	0.6	-0.4
	II	Jan. 28, 1911	May 2, 1911	94	11.1	5.4	8.2	9.7	6.2	8.0	—1.3	0.8	—0.2
	III	Jan. 28, 1911	May 2, 1911	94	11.1	5.4	8.2	9.7	6.1	7.9	—1.3	0.7	—0.3
O	I	Jan. 28, 1911	April 26, 1911	88	13.0	5.4	9.2	11.0	6.5	8.7	—2.0	1.1	0.5
	II	Jan. 28, 1911	May 2, 1911	94	13.0	5.4	9.2	11.1	6.8	9.0	—1.9	1.4	—0 2
	III	Jan. 28, 1911	May 2, 1911	94	13.0	5.4	9.2	11.3	6.9	9.1	—1.7	1.5	-0 1
P	I	Jan. 28, 1911	April 26, 1911	88	15.1	5 4	10.2	12.2	7.3	9.7	—2.9	1.9	-0.5
	II	Jan. 28, 1911	May 2, 1911	94	15.1	5.4	10.2	12.6	7.2	9.9	- 2.5	1.8	—0.3
	III	Jan. 28, 1911	May 2, 1911	94	15.1	5.4	10.2	12.6	7.2	9.9	2.5	1.8	—0.3
Q	I	Dec. 20, 1911	Feb. 23, 1912	65	15.8	6.2	11.0	13.4	8.0	10.7	—2 4	1.8	—0.3
	II	Dec. 20, 1911	March 29, 1912	100	15.8	6.2	11.0	13.4	8.6	11.0	—2.4	2.4	0.0
R	I	Dec. 20, 1911	Feb. 19, 1912	61	17.8	6.2	12.0	14.9	8.4	11.7	-2.9	2.2	-0.3
	II	Dec 20, 1911	March 18, 1912	89	17.8	6.2	12.0	14.6	8.8	11.7	3.2	2.6	—0.3
S	I	Dec. 20, 1911	Feb. 21, 1912	63	22.8	6.2	14.5	17.9	9.7	13.8	—4.9	3.5	—0.7
	II	Dec. 20, 1911	March 21, 1912	92	22.8	6.2	14.5	17.8	10.0	13.9	—5.0	3.8	—0.6
T	I	Dec. 20, 1911	March 28, 1912	99	25.4	6.2	15.8	20.1	11.8	16.0	5.3	5.6	0.2
	II	Dec. 20, 1911	March 29, 1912	100	25.4	6.2	15.8	19.6	12.3	15.9	-5.8	6.1	0.1
U	I	Dec. 20, 1911	Feb. 22, 1912	64	27.1	6.2	16.6	20.6	12.8	16.7	—6.5	6.6	0.1
	II	Dec. 20, 1911	Feb. 23, 1912	65	27.1	6.2	16.6	20.1	13.1	16.6	—6.0	5.9	0.0

TABLE 6.—*The downward movement of water from a moist soil into a drier soil.*

SERIES K.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	9.4	7.8	7.5	7.9	7.7	1.7	.....
3 and 4	9.4	7.8	7.7	7.7	7.7	1.7	.....
5 and 6	9.4	7.8	7.6	7.6	7.7	1.7	.....
7 and 8	9.4	7.7	7.6	7.7	7.7	1.7	.....
9 and 10	9.4	7.4	7.5	7.4	7.4	2.0	.....
11 and 12	9.4	7.0	7.2	7.0	7.1	2.3	.....
13 and 14	3 4	5.2	5.4	5.3	5.3	.....	2.0
15 and 16	3.4	4.3	4.4	4.5	4.4	.....	1.0
17 and 18	3.4	4.2	4.1	4.0	4.1	.....	0.7
19 and 20	3.4	4.2	4.1	4.1	4.1	.....	0.7
21 and 22	3.4	4.1	3.4	4.0	3.8	.....	0.4
23 and 24	3.4	4.3	3.2	3.8	3.8	.....	0.4
Average	6.4	6.0	5.8	5.9	5.9	.....	.....

SERIES L.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II April 26	Cyl. III April 26	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	7.3	6.6	6.4	6.5	6.5	0.8	.....
3 and 4	7.3	6.7	6.4	6.5	6.5	0.8	.....
5 and 6	7.3	6.7	6.4	6.5	6.5	0.8	.....
7 and 8	7.3	6.7	6.8	6.4	6.6	0.7	.....
9 and 10	7.3	6.7	6.8	6.4	6.6	0.7	.....
11 and 12	7.3	5.8	6.5	6.4	6.2	1.1	.....
13 and 14	5.4	5.9	5.8	5.8	5.8	.....	0.4
15 and 16	5.4	5.6	5.7	5.5	5.6	.....	0.2
17 and 18	5.4	5.6	5.8	5.5	5.6	.....	0.2
19 and 20	5.4	5.5	5.6	5.5	5.5	.....	0.1
21 and 22	5.4	5.5	5.6	5.5	5.5	.....	0.1
23 and 24	5.4	5.9	5.7	5.7	5.8	.....	0.4
Average	6 3	6.1	6.1	6.0	6.1	.....	.....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES M.

Depth of section	Cyls. I to III Jan. 26	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	9.1	8.1	8.0	8.1	8.1	1.0	.....
3 and 4	9.1	8.0	7.9	8.1	8.0	1.1	.....
5 and 6	9.1	8.0	8.1	8.1	8.1	1.0	.....
7 and 8	9.1	8.1	8.1	8.2	8.1	1.0	.....
9 and 10	9.1	7.9	8.1	8.2	8.1	1.0	.....
11 and 12	9.1	7.7	7.9	8.2	7.9	1.2	.....
13 and 14	5.4	6.3	6.6	7.0	6.6	.....	1.2
15 and 16	5.4	5.7	6.2	6.0	6.0	.....	0.6
17 and 18	5.4	5.5	5.7	5.9	5.7	.....	0.3
19 and 20	5.4	5.4	5.7	5.7	5.6	.....	0.2
21 and 22	5.4	5.6	5.8	5.7	5.7	.....	0.3
23 and 24	5.4	5.8	5.8	5.7	5.8	.....	0.4
Average	7.2	6.8	7.0	7.1	7.0	.....	.....

SERIES N.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	11.0	9.7	9.3	9.7	9.7	1.3	.....
3 and 4	11.0	9.7	9.7	9.8	9.7	1.3	.....
5 and 6	11.0	9.5	9.8	9.8	9.7	1.3	.....
7 and 8	11.0	9.5	9.8	9.7	9.7	1.3	.....
9 and 10	11.0	9.5	9.8	9.8	9.7	1.3	.....
11 and 12	11.0	9.2	9.6	9.2	9.3	1.7	.....
13 and 14	5.4	7.3	7.7	7.3	7.4	.....	2.0
15 and 16	5.4	6.3	6.6	6.5	6.5	.....	1.1
17 and 18	5.4	5.7	6.0	5.9	5.9	.....	0.5
19 and 20	5.4	5.6	5.7	5.6	5.6	.....	0.2
21 and 22	5.4	5.4	5.5	5.4	5.4	.....	0.0
23 and 24	5.4	5.8	5.7	5.6	5.7	.....	0.3
Average	8.2	7.8	8.0	7.9	7.9	.....	.....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES O.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	13.0	11.1	11.0	11.2	11.1	1.9	.....
3 and 4	13.0	11.1	11.1	11.2	11.1	1.9	.....
5 and 6	13.0	11.0	11.0	11.7	11.2	1.8	.....
7 and 8	13.0	11.2	11.2	11.0	11.1	1.9	.....
9 and 10	13.0	11.1	11.1	11.2	11.1	1.9	.....
11 and 12	13.0	10.5	11.1	11.2	10.9	2.1	.....
13 and 14	5.4	8.3	8.7	8.8	8.6	.....	3.2
15 and 16	5.4	7.4	8.0	7.7	7.7	.....	2.3
17 and 18	5.4	6.3	7.0	6.9	6.7	.....	1.3
19 and 20	5.4	5.7	6.0	6.2	6.0	.....	0.6
21 and 22	5.4	5.5	5.7	5.9	5.7	.....	0.3
23 and 24	5.4	5.6	5.6	5.9	5.7	.....	0.3
Average	9.2	8.7	9.0	9.1	8.9	.....	.....

SERIES P.

Depth of section	Cyls. I to III Jan. 28	Cyl. I April 26	Cyl. II May 2	Cyl. III May 2	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1 and 2	15.1	12.2	12.4	12.4	12.3	2.8	.....
3 and 4	15.1	12.2	12.7	12.4	12.4	2.7	.....
5 and 6	15.1	12.4	12.8	12.5	12.6	2.5	.....
7 and 8	15.1	12.4	12.7	12.5	12.5	2.6	.....
9 and 10	15.1	12.4	12.7	12.7	12.6	2.5	.....
11 and 12	15.1	11.5	12.1	12.8	11.8	3.3	.....
13 and 14	5.4	8.8	9.2	8.9	9.0	.....	3.5
15 and 16	5.4	8.2	8.4	8.3	8.3	.....	2.9
17 and 18	5.4	7.5	7.4	7.5	7.5	.....	2.1
19 and 20	5.4	6.6	6.4	6.5	6.5	.....	1.1
21 and 22	5.4	6.2	5.9	6.0	6.0	.....	0.6
23 and 24	5.4	6.3	5.9	6.2	6.1	.....	0.7
Average	10.2	9.7	9.9	9.9	9.8	.....	.....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES Q.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 23	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	15.8	13.3	13.7	13.5	2.3	
2	15.8	13.5	13.3	13.4	2.4	
3	15.8	13.7	13.4	13.5	2.3	
4	15.8	13.7	13.5	13.6	2.2	
5	15.8	13.5	13.4	13.5	2.3	
6	15.8	13.6	13.6	13.6	2.2	
7	15.8	13.6	13.6	13.6	2.2	
8	15.8	13.5	13.5	13.5	2.3	
9	15.8	13.5	13.6	13.5	2.3	
10	15.8	13.7	13.6	13.6	2.2	
11	15.8	13.7	13.7	13.7	2.1	
12	15.8	11.8	12.5	12.2	3.6	
13	6.2	10.1	10.3	10.2		4.0
14	6.2	9.8	9.9	9.9		3.7
15	6.2	9.4	9.5	9.5		3.3
16	6.2	8.9	9.2	9.0		2.8
17	6.2	8.4	9.1	8.7		2.5
18	6.2	8.1	8.6	8.4		2.2
19	6.2	7.6	8.3	7.9		1.7
20	6.2	7.1	7.9	7.5		1.3
21	6.2	6.9	7.5	7.2		1.0
22	6.2	6.6	7.6	7.1		0.9
23	6.2	6.6	7.6	7.1		0.9
24	6.2	6.0	7.8	6.9		0.7
Average	11.0	10.7	11.0	10.9		

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES R.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 19	Cyl. II March 18	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	17.8	14.8	14.9	14.8	3.0	.....
2	17.8	14.8	14.5	14.7	3.1	.....
3	17.8	14.8	14.6	14.7	3.1	.....
4	17.8	14.9	14.6	14.7	3.1	.....
5	17.8	14.9	14.7	14.8	3.0	.....
6	17.8	15.0	14.6	14.8	3.0	.....
7	17.8	15.0	14.6	14.8	3.0	.....
8	17.8	15.2	14.5	14.8	3.0	.....
9	17.8	15.0	14.6	14.8	3.0	.....
10	17.8	15.0	14.5	14.8	3.0	.....
11	17.8	15.2	14.6	14.9	2.9	.....
12	17.8	15.0	14.2	14.6	3.2	.....
13	6.2	11 1	10.1	10.6	.....	4.4
14	6.2	10.3	10.1	10.2	.....	4.0
15	6.2	9.8	9.8	9.8	.....	3.6
16	6.2	9.1	9.5	9.3	.....	3.1
17	6.2	8.5	9.4	8.9	.....	2.7
18	6.2	8.4	9.0	8.7	.....	2.5
19	6.2	7.7	8.9	8.3	.....	2.1
20	6.2	7.4	8.3	7.8	.....	1.6
21	6.2	7.1	7.9	7.5	.....	1.3
22	6.2	6.9	7.7	7.3	.....	1.1
23	6.2	7.0	7.5	7.3	.....	1.1
24	6.2	7.2	7.6	7.4	.....	1.2
Average	12.0	11.7	11.7	11.7	.....	.....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES S.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 21	Cyl. II March 21	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	22.8	17.1	17.1	17.1	5.7	
2	22.8	18.6	18.0	18.3	4.5	
3	22.8	18.0	17.8	17.9	4.9	
4	22.8	18.0	17.5	17.7	5.1	
5	22.8	18.2	18.2	18.2	4.6	
6	22.8	18.2	18.2	18.2	4.6	
7	22.8	18.2	18.0	18.1	4.7	
8	22.8	18.3	18.1	18.2	4.6	
9	22.8	18.2	18.2	18.2	4.6	
10	22.8	18.2	18.2	18.2	4.6	
11	22.8	18.2	18.0	18.1	4.7	
12	22.8	15.2	14.9	15.0	7.8	
13	6.2	11.4	11.1	11.3		5.1
14	6.2	11.1	10.7	10.9		4.7
15	6.2	10.9	10.6	10.7		4.5
16	6.2	10.6	10.5	10.5		4.3
17	6.2	10.3	10.1	10.2		4.0
18	6.2	10.0	9.8	9.9		3.7
19	6.2	9.6	9.7	9.6		3.4
20	6.2	9.5	9.5	9.5		3.3
21	6.2	8.9	9.5	9.2		3.0
22	6.2	8.6	9.4	9.0		2.8
23	6.2	8.3	9.4	8.8		2.6
24	6.2	8.3	9.4	8.8		2.6
Average	14.5	13.8	13.9	13.8		

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Continued.*

SERIES T,

Depth of section	Cyls. I, II Dec. 20	Cyl. I March 28	Cyl. II March 29	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	25.4	19.4	19.8	19.6	5.8	.....
2	25.4	20.4	20.2	20.3	5.1	.....
3	25.4	20.2	20.0	20.1	5.3	.....
4	25.4	20.4	19.7	20.0	5.4	.....
5	25.4	20.3	19.7	20.0	5.4	.....
6	25.4	20.2	19.8	20.0	5.4	.....
7	25.4	20.2	20.0	20.1	5.3	.....
8	25.4	20.0	20.0	20.1	5.3	.....
9	25.4	20.5	19.9	20.0	5.4	.....
10	25.4	20.3	19.9	20.2	5.2	.....
11	25.4	20.4	20.0	20.1	5.3	.....
12	25.4	18.9	16.6	17.7	7.7	.....
13	6.2	13.5	13.2	13.3	.....	7.1
14	6.2	12.3	12.8	12.5	.....	6.3
15	6.2	12.1	12.6	12.3	.....	6.1
16	6.2	12.0	12.4	12.2	.....	6.0
17	6.2	12.1	12.0	12.1	.....	5.9
18	6.2	11.8	11.9	11.9	.....	5.7
19	6.2	11.6	12.0	11.8	.....	5.6
20	6.2	11.3	12.0	11.7	.....	5.5
21	6.2	11.5	12.2	11.8	.....	5.6
22	6.2	11.3	12.2	11.8	.....	5.6
23	6.2	11.3	12.3	11.8	.....	5.6
24	6.2	11.3	12.1	11.7	.....	5.5
Average	15.8	16.0	15.9	16.0	.....	.....

TABLE 6.—*The downward movement of water from a moist soil into a drier soil—Concluded.*

SERIES U.

Depth of section	Cyls. I, II Dec. 20	Cyl. I Feb. 22	Cyl. II Feb. 23	Average	Loss	Gain
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	27.1	20.7	20.0	20 3	6.8	
2	27.1	21.0	20.5	20.7	6.4	
3	27.1	20.9	20.0	20.4	6.7	
4	26.1	20.9	19.9	20.4	6.7	
5	27.1	20.6	20.2	20.4	6.7	
6	27.1	21.1	20.2	20.6	6.5	
7	27.1	20.8	20.2	20.5	6.6	
8	27.1	20.8	20.0	20.4	6.7	
9	27.1	20.5	20.0	20.3	6.8	
10	27.1	20.5	20.2	20.3	6.8	
11	27.1	20.8	20.1	20.4	6.7	
12	27.1	19.2	19.7	19.5	7.6	
13	6.2	14 0	14.1	14.0		7.8
14	6.2	13.5	14.0	13.7		7.5
15	6.2	13.2	13.5	13.3		7.1
16	6.2	13.1	13.2	13.1		6.9
17	6.2	13.0	12.8	12.9		6.7
18	6 2	12.6	12.9	12.7		6.5
19	6.2	12.6	12 9	12.7		6.5
20	6.2	12.4	12.8	12.6		6.4
21	6.2	12.3	12.7	12.5		6.3
22	6.2	12.3	12.7	12.5		6.3
23	6.2	12.6	12.9	12.7		6.5
24	6.2	12.6	12.9	12.7		6.5
Average	16.6	16.7	16.6	16.7		

EXPERIMENT 3.—THE DOWNWARD MOVEMENT OF WATER IN A SOIL COLUMN IN CAPILLARY CONNECTION WITH THE NATURAL SUBSOIL BUT PROTECTED FROM EVAPORATION

When a soil is placed in a cylinder with a perforated bottom, saturated with water, and allowed to drain, the water content is not reduced to the same point that it is when the soil is in direct connection with a large amount of dry or only fairly moist soil of similar or of finer texture.

On March 11, 1912, three cylinders 3 feet long, 6 inches in diameter, and open at both ends, were placed in holes 8 inches in diameter which were bored in the loess floor of a greenhouse. The open space surrounding each cylinder was packed very tightly with subsoil in order to hold the cylinder firmly in place. Then air-dried soil was filled into the cylinders to a depth of thirty inches, tamping it as above described. Thus, direct capillary connection could be established between the soil of the cylinder and the natural subsoil. The moisture condition of the latter at a depth of three feet was about the same as in the field. On the tamped soil a two-inch layer of gravel was placed and 15 pounds of water added as rapidly as it soaked away—about 15 hours being required. As soon as all the water had been added, the tops of the cylinders were closed with tightly-fitting covers and a layer of moist soil, eight inches in depth, placed over all to prevent any evaporation and to protect the cylinders from the heat. As the weight of air-dried soil in each cylinder was approximately 50 pounds, the added water was sufficient to have raised the moisture content to over 30 per cent if no seepage had occurred. At intervals the cylinders were opened one by one and the moisture content determined by inch sections. The data are given in Table 7. At the end of seven weeks equilibrium had not yet been attained, the moisture content continuing to fall. The highest percentage found was shown by the lowest inch section and in this it was less than 27 per cent. Above the eighteenth

inch it did not exceed 21 per cent, while in the uppermost foot it was approximately 18 per cent. Accordingly, the soil in some of the series reported in Tables 3 and 5 was as moist as it is likely to ever be found in the field.

TABLE 7.—*Downward movement of water in a uniform soil entirely protected from evaporation but in capillary connection with the earth's soil mass. Series V. On February 15 to the cylinders filled with approximately 50 pounds of air-dried soil there was added 15 pounds of water.*

Depth of section	Cylinder I March 18	Cylinder II April 1	Cylinder III April 10
Inches	*Per cent*	*Per cent*	*Per cent*
1	17.4	18.5	17.3
2	17.2	17.8	16.9
3	17.2	17.8	17.1
4	17.7	17.8	17.2
5	18.3	17.8	17.2
6	18.1	....	17.5
7	18.0	17.9	17.6
8	18.4	18.6	18.0
9	19.1	18.8	18.3
10	18.7	19.3	18.7
11	19.2	19.6	18.8
12	19.8	19.3	18.6
13	20.0	18.9	....
14	20.4	19.7	19.1
15	20.8	20.2	19.3
16	20.2	19.3	19.4
17	20.5	20.1	19.6
18	20.7	21.9	19.8
19	20.5	20.8	19.9
20	20.7	20.5	20.3
21	21.4	21.6	20.5
22	22.5	23.1	21.1
23	23.3	22.1	21.2
24	23.7	21.8	21.6
25	23.8	22.0	22.9
26	24.5	23.9	23.4
27	25.1	25.2	23.8
28	25.4	24.1	23.6
29	26.0	23.9	25.1
30	26.7	24.0	26.0
Average	22.8	20.6	20.0

EXPERIMENT 4.—THE MOVEMENT OF WATER IN A SOIL COLUMN FULLY EXPOSED TO EVAPORATION AT THE SURFACE

In this experiment four water-tight cylinders, 6 inches in diameter, 3 feet deep, and closed at the bottom, were sunk in holes in the greenhouse as described above, but the tops of the cylinders were placed level with the surface of the greenhouse floor and left open. On February 14, 1912, they were filled with soil containing 11.8 per cent of water. The soil was tamped in as usual, this being continued to the top in the case of two and to within an inch of the top in the case of the other two. In the latter two the top inch was filled with air-dried soil. The cylinders were so situated that the sun shone on them nearly all day, no whitewash being used on the plant house windows until near the close of the experiment. The mean daily temperature was not far from 75° F. thruout the time of the exposure, the daily maximum usually rising above 90° F.

The cylinders were examined daily for the presence of minute cracks on the surface of the packed soil of the two cylinders and of crevices around the walls of all four. As soon as cracks or crevices appeared they were filled with dry soil from the surface, so that all water lost would have to pass thru the surface soil instead of part of it escaping thru such ventilating fissures.

The humidity and the temperature of the air, as well as the temperature of the soil, were probably more favorable for rapid evaporation than is the case under field conditions in Nebraska. There was, however, but very little air movement.

The data are given in Table 8. There was a steady loss of water, it being greatest at the surface and least toward the bottom of the cylinders. At the end of 22 days no loss at all was shown by the soil near the bottom of the cylinders, but at the end of 77 days even the lowest portions had suffered a loss of about 1 per cent. A uniform upward movement similar to that mentioned above in Experiments 1 and 2 is to be observed in the case

of the lowest eight to eleven inches. The soil in these cylinders, having an initial water content of 11.8 per cent, was much like that in Series D which had 12.1 per cent. After 77 days' exposure, that below the surface foot was similar to the soil in the lower half of Series A and C; hence, all further losses would be expected to take place very slowly.

In the case of III and IV, the moisture in the seventeenth and eighteenth inches is lower than either above or below. Seeking an explanation for this we found a return steam pipe below the earth floor of the greenhouse at this level, but at a distance of 14 inches.

TABLE 8.—*Loss of water from a uniform soil protected from all loss at the sides and below, but fully exposed to evaporation at the surface. Series W. All the cylinders were filled on February 14 with soil containing 11.8 per cent water.*

Depth of Section	Water content on opening cylinder				Loss of water			
	March 7		May 1		In 22 days		In 77 days	
	Cyl. I Surface m'lch'd	Cyl. II Surface packed	Cyl. III Surface m'lch'd	Cyl. IV Surface packed	Cyl. I	Cyl. II	Cyl. III	Cyl. IV
Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	3.0	3.3	2.2	2.2	8.8	8.5	9.6	9.6
2	4.4	6.5	2.2	2.4	7.4	5.3	9.6	9.4
3	7.4	8.2	3.8	4.6	4.4	3.6	8.0	7.2
4	8.8	8.6	5.6	6.2	3.0	3.2	6.2	5.6
5	9.1	9.1	6.8	7.4	2.7	2.7	5.0	4.4
6	9.5	9.4	7.4	7.8	2.3	2.4	4.4	4.0
7	9.5	10.0	7.8	8.8	2.3	1.8	4.0	3.0
8	9.7	10.1	8.1	8.6	2.1	1.7	3.7	3.2
9	9.9	10.1	8.3	8.9	1.9	1.7	3.5	2.9
10	10.1	10.3	9.0	9.1	1.7	1.5	2.8	2.7
11	10.3	10.5	9.1	9.4	1.5	1.3	2.8	2.4
12	10.4	10.6	9.2	9.5	1.4	1.2	2.6	2.3
13	10.6	10.8	9.7	9.5	1.5	1.0	2.1	2.3
14	10.9	10.9	10.0	9.8	1.5	.9	1.8	2.0
15	11.0	11.1	10.0	10.1	1.2	.7	1.8	1.7
16	11.2	11.2	9.9	10.0	.9	.6	1.9	1.8
17	11.0	11.4	9.8	9.9	.8	.4	2.0	1.9
18	11.1	11.4	9.9	9.9	.6	.4	1.9	1.9
19	11.1	11.4	10.0	10.7	.8	.4	1.8	1.1
20	11.1	11.4	10.0	10.6	.7	.4	1.8	1.2
21	11.2	11.4	10.1	10.2	.7	.4	1.7	1.2
22	11.4	11.4	10.2	10.3	.7	.4	1.7	1.6
23	11.4	11.4	10.4	10.3	.6	.4	1.6	1.5
24	11.5	11.4	10.5	10.4	.4	.4	1.4	1.5
25	11.4	11.4	10.6	10.7	.4	.4	1.3	1.4
26	11.5	11.5	10.7	10.8	.3	.3	1.2	1.1
27	11.4	11.5	10.7	10.7	.4	.3	1.1	1.0
28	11.5	11.5	10.9	10.7	.3	.3	1.1	1.1
29	11.5	11.6	10.9	10.8	.3	.2	.9	1.1
30	11.5	11.7	11.0	10.8	.3	.1	.9	1.0
31	11.5	11.7	11.0	10.8	.3	.1	.8	1.0
32	11.5	11.7	11.0	10.8	.3	.1	.8	1.0
33	11.5	11.8	11.0	10.8	.3	.0	.8	1.0
34	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
35	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
36	11.8	11.8	11.0	10.8	.0	.0	.8	1.0
Average	10.3	10.6	9.2	9.4	1.5	1.2	2.6	2.4

EXPERIMENT 5.—THE DOWNWARD MOVEMENT OF WATER APPLIED TO THE SURFACE OF A COLUMN OF AIR-DRIED SOIL

In this experiment six cylinders, each 18 inches long, 6 inches in diameter, closed at the bottom, and provided with a tightly-fitting cover, were used. Twelve inches of air-dried soil containing 2.3 per cent of water was tamped into each and the volume of water, equivalent to one, two, or three inches of rain, was added to the surface in small portions as rapidly as it was absorbed, after which an inch layer of gravel was added to the surface, the cylinders covered, placed in the pit, and left undisturbed for 47 days. Then they were removed, opened, and the water determined in inch sections. The data are given in Table 9.

Where one inch of water had been added, the moisture was distributed uniformly to a depth of 3 or 4 inches, below which it decreased very rapidly, but where twice as much was added the moist soil extended to the bottom of the foot, while with three inches of added water the soil was very moist thruout.

TABLE 9.—*Distribution of water in cylinders in which different amounts of water were applied to the surface of the columns of air-dried soil, after which the cylinders were allowed to stand 47 days. The air-dried soil contained 2.3 per cent water.*

One inch water added				Two inches water added			Three inches water added		
Depth	Cyl. I	Cyl. II	Average	Cyl. I	Cyl. II	Average	Cyl. I	Cyl. II	Average
Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1.....	10.8	10.6	10.7	14.7	15.5	15.1	21.7	23.2	22.4
2.....	10.3	10.4	10.3	14.3	14.6	14.4	20.1	21.1	20.6
3.....	10.3	10.1	10.2	14.1	14.3	14.2	19.7	20.3	20.0
4.....	10.3	9.8	10.1	14.2	14.4	14.3	19.8	20.2	20.0
5.....	9.3	9.4	9.3	13.4	13.9	13.6	19.5	20.3	19.9
6.....	8.9	8.6	8.8	13.9	12.2	13.0	19.7	20.0	19.8
7.....	7.5	7.4	7.4	13.4	12.5	12.9	19.6	19.9	19.7
8.....	5.7	5.2	5.4	12.9	11.9	12.4	19.2	18.7	18.9
9.....	5.5	4.9	5.2	12.0	11.3	11.7	17.5	16.9	17.1
10.....	4.8	4.5	4.7	11.3	11.1	11.2	16.2	15.9	16.1
11.....	4.4	4.1	4.2	11.4	11.0	11.2	15.8	15.5	15.7
12.....	4.3	3.9	4.1	11.3	11.0	11.1	16.2	16.4	16.3
Av.....	7.7	7.4	7.6	13.1	12.8	12.9	18.7	19.0	18.9

SUMMARY

The soil used in the experiments was typical of the subsoil of a large area of the semiarid portion of Nebraska and could be placed in the cylinders in a condition very similar to that in which it naturally occurs. It had a hygroscopic coefficient of 5.6 and the maximum water capacity was 55.

When the water content was below 10 per cent, the capillary movement of moisture in any direction was slight; but when some of the soil with a moisture content of above 10 per cent was placed in contact with the same soil containing only the maximum hygroscopic moisture, there was a practically uniform movement of water from all parts of the former into the latter, except that immediately adjoining the drier soil the change was much the greatest. The higher the water content the greater was the movement of water.

When soil with a moisture content of approximately 12 per cent was freely exposed to evaporation from the surface, no loss by capillary movement occurred to a depth of 30 inches until after the third week, but by the end of eleven weeks the loss from this depth amounted to 1.0 per cent.